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PHILADELPHIA
THE AMERICAN PHILOSOPHICAL SOCIETY
104 South Fifth Street
1905

GENERAL MEETING—1906

The next General Meeting of the Society will be held on April 17-20, 1906: beginning on the evening of Tuesday, April 17.

Wednesday, April 18, will be devoted to the presentation and discussion of scientific papers, and Thursday, 19 and Friday, 20, to the ceremonies connected with the celebration of the 200th Anniversary of the Birth of Benjamin Franklin.

Members desiring to present papers on subjects of science at the General Meeting are requested to communicate with the Secretaries at the earliest possible date.

Members who have not as yet sent their photographs to the Society will confer a favor by so doing: cabinet size preferred.

It is requested that all correspondence be addressed

To the Secretaries of the

American Philosophical Society

104 South Fifth Street

Philadelphia, U. S. A.

PROCEEDINGS

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AMERICAN PHILOSOPHICAL SOCIETY

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VOL. XLIV. JANUARY–APRIL, 1905. NO. 179.

Stated Meeting, January 6, 1905.

President SMITH in the Chair.

The resignation of membership by Prof. Charles De Garmo, was presented and accepted.

The decease of the following members was announced:

Prof. Benjamin W. Frazier, at Bethlehem, Pa., on January 4, 1905, æt. 64.

Edward H. Weil, at Philadelphia, on January 5, 1905, æt. 68.

The Judges of the Annual Election of Officers and Councillors reported that an election had been held on the afternoon of this day and that the following named members had been elected to be the officers for the ensuing year:

President

Edgar F. Smith.

Vice-Presidents

George F. Barker, William B. Scott, Simon Newcomb.

Secretaries

I. Minis Hays, Edwin G. Conklin, Arthur W. Goodspeed, Morris Jastrow, Jr.

Curators

Charles L. Doolittle, William P. Wilson, Albert H. Smyth.

Treasurer

Henry La Barre Jayne.

Councillors to serve for three years

George F. Edmunds, James T. Mitchell, Joseph Wharton, William W. Keen.

Stated Meeting, January 20, 1905.

President SMITH in the Chair.

The decease of the following members was announced:

Sir Lowthian Bell, Bart, at North Allerton, Eng., on December 20, 1904, æt. 88.

Dr. C. Juhlin Dannefeld, of Stockholm.

The following papers were read:

"Biblical Pessimism," by Prof. Paul Haupt.

"Universal Radio-Activity," by Prof. M. B. Snyder.

Stated Meeting, February 3, 1905.

President SMITH in the Chair

The decease was announced of Mr. William Sellers, at Philadelphia, on January 24, 1905, æt. 81.

Prof. Edwin G. Conklin read a paper on "Development and Evolution."

Stated Meeting, February 17, 1905.

President SMITH in the Chair

The decease was announced of Prof. Alpheus Spring Packard, at Providence, on February 14, 1905, æt. 66.

Prof. Amos P. Brown read a paper on "The Rocky Mountains."

Stated Meeting, March 3, 1905.

President SMITH in the Chair.

The decease was announced of Prof. Albert Benjamin Prescott, at Ann Arbor, Mich., on February 25, 1905, æt. 72.

Prof. Hermann V. Hilprecht read a paper on "Recent Researches in the Temple Library at Nippur."

Stated Meeting, March 17, 1905.

President SMITH in the Chair.

The decease of the following members was announced:

Prof. John Lyle Campbell, at Crawfordsville, Ind., on September 7, 1904, æt. 77.

Hon. James C. Carter, at New York, on February 14, 1905, æt. 78.

Richard Somers Hayes, at New York, on March 2, 1905, æt. 58.

James Dundas Lippincott, at Philadelphia, on March 6, 1905, æt. 66.

The following papers were read:

"The Filipino, his Customs and Character," by Dr. J. A. Metgzer. (See page 6.)

"The Sociology of the Aborigines of Western Australia," by R. H. Mathews. (See page 32.)

THE FILIPINO; HIS CUSTOMS AND CHARACTER.

BY JOHN A. METZGER, M.D.

(*Read March 17, 1905.*)

The early history of the people of the Philippines can, unfortunately, be none other than that of imperfect conjecture. We do know, however, that the present-day Filipino is not the direct, unalloyed descendent of the aboriginal inhabitants of these islands but have lineage from some nomadic people who, through affiliation with the aborigines, have given to the ethnologist this almost incomprehensible human being. The progenitorial element is unquestionably Malayan but the source is a much debated question. Some authorities contend that the ancestors of this great semi-civilized people came from Chili, drifted thither by the currents and prevailing winds, while others with as equitable reasoning believe them to have migrated from the shores of Madagascar and Patagonia. Neither the paleontologist nor the paleographer has thus far been able to throw any definite light on the source or character of the original inhabitants of th s dependency. However, the generally accepted theory points to a mountain tribe called the Negrito or Ætas, which is universally regarded as the surviving remnant of this once powerful people who first populated the archipelago.

From a paleontological and structural point of view we are wont to believe that during the later Miocene or the very early Pliocene, there was that progressive uplifting of the land which subsequently became separated from Borneo and the Asiatic continent (through Formosa) by the present China sea. The evidence which warrants this deduction must be admitted is very fragmentary, however, the distribution of living forms is certainly calculated to throw some light on the more recent history of these islands and should be made to contribute all it can, but at the same time it must not be forgotten that the obstacles which seem geologically of small moment may limit the extension of species. The island of Cebú affords a striking example of this fact regarding the bird fauna and mammalia which are regarded as the descendant forms of Borneo and Continental Asia. This theory is corroborated by Mr. Waller,

who has given this considerable study, when he says: "Absence of a large number of Malayan groups would indicate that the actual connection with Borneo, which seems necessary for the introduction of the Malayan types of mammalia, with the large proportion of wide-spread continental genera of birds would seem to imply that greater facilities had once existed for the migration from Southern China, at which time the ancestors of that peculiar deer seen in Samar and Cebú entered the islands." It, therefore, seems impossible to understand this existing fauna unless it can be assumed that island connection must have existed. Accepting this theory, why then should not primitive man have made his ingress from Borneo or Continental Asia? This question of the aboriginese is indeed a field for research and is one for the ethnologist and not the province of a mind inexperienced in this line of study.

Conceding for the present the Negrito to have been the aboriginal inhabitants, we have as yet to discover any signs or writings of an early day which might lead us to a solution of the origin of this strange tribe. We have, however, characters, many of which are hieroglyphical, of the ancient Tagalog, Visayan, Yliocano, Pampañgo, Pañgasinan and Tagbañua. These characters were expressed or inscribed on tubes of bamboo, with some pointed instrument the nature of which is as yet unknown, and like the present-day dialects of the several tribes there seems to have been a great preponderance of consonants and a very limited vocabulary. A comma above a letter, should it be a consonant, gave it the sound of having been written with an E or I, and if below as O or U.

Upon the conquest of the archipelago by the Spaniard their alphabets were abandoned by many and the Spanish or the original of the present mongrel dialects were adopted and after a period of three hundred years there is scarcely a person to be found who can either read or write in the original characters. This, however, is the field of the paleographer but, I believe, is worthy of mention in this connection. The adoption of the Spanish language by some of the tribes was the first step in the domestication of these people, in that it permitted the placing of the Doctrina in their hands with the consequent closer affiliation. (For those wishing to further investigate these early languages of the Filipino, I would refer them to the writings of the Agustinian father Marcilla, and especially his "Estudio de los antigues alfabetos Filipinos.")

Of the fifty odd different tribes there are almost as many distinct dialects, however, with few exceptions, there is a general similarity which permits of mutual comprehension. There are not only many words in common peculiar to the native tongue but Spanish words have been adopted into most of the dialects. The Tagalog and

Fig. 1. Negritos.

Yliocano are probably the most general in the northern country, while the Visayan and the Mahratte dialect of the mother Sanskrit predominate in the middle and south lands.

The Tagalog, Yliocano and Viscayan are gutteral languages or great preponderance of consonants and limited vocabularies.

The remnant of the tribe of Negritos, the supposed descendants

of the aboriginese, scarcely number five thousand at the present time and are scattered widely over all the northern islands, living in the most remote and dense parts of the hill country. They are pygmean in stature, barely reaching four and one half feet in height and resembling closely the Alfoor Papuan of New Guinea. Although small in frame they are powerful andfleet of foot. Unlike any of the other tribes of this archipelago they are the possessors of a closely matted kinked head of hair. The Negrito is of very low intellect and appreciates no conception of social order. He is cowardly and indolent, but exhibits a marked respect for the aged and dead such as is not seen among any of the other tribes. Frequent attempts have been made to civilize these little people but without success, for they will neither endure social or military restraint but prefer to return to the mountain fastnesses and their nomadic state. Model villages of bamboo and nepá were built in Upper Pampañga by the Spaniards with the object of domesticating these strange people. They were supplied with food, clothing and all the necessaries of life for a period of one year or until such a time as they could till the soil and provide for their future but the experiment was an utter failure and in a short time the subsidy was discontinued. They have never been either individually or collectively brought under the influence of the Church but to this day continue to worship the sun and elements as did their forefathers. The Negrito subsists wholly upon reptiles, fish, herbs and wild mountain rice. They wear no clothing except the breech-clout and their customs and habits are those of the savage. Ablution of body is something almost unknown to them. These little people have no permanent abode but wander about in little bands of five to twenty living in trees as a matter of safety. They are more or less peacefully inclined but do occasionally make incursions into the territory of some neighboring tribe for the purpose of carrying off cattle. Their means of defense is a bow made from the palmabrava and poisoned arrows, and with these they are indeed expert marksmen. There is no doubt but that at an early period in the history of these islands these dwarfish-people were in great numbers and as rulers levied heavy tribute upon the accessors of some of the present day tribes, but as emigration increased they were gradually forced into the background and subsequently, upon the advent of the white-man, were forced, through terror, to take definitely to the mountain fastness.

The exact number of tribes in existence on the several islands at the present time is not definitely known, however, the following are a few of those which we as a foster nation must deal with: Tagalog, Viscayan, Macabebe, Yliocano, Musulman, Igorrote, Malaneg, Pampañgan, Pañgasinan, Itanes, Goddan, Tiñguian, Dodayan, Idayan, Apayao, Negrito, Itugoao, Ibiloa, Zambal, Vrigrito, Cebúano, Panayano, Munabo, Coyuro, Calamino, Agutamo, and that great hybrid class, the Maestizo. Other of the fifty-two tribes, which have thus far been determined, might be mentioned, but I believe it to be superfluous here, as their customs are in the main those of the aforementioned. In this ethnical analysis I have dealt solely with generic denominations, for whilst these tribes are subdivided, the clans show no material moral or physical difference and the local names are apt to be confusing. Lie,siwe, in order to avoid prejudice, it becomes necessary to divide this great congeries of humanity into two great classes, the domesticated Filipino and the properly termed savage. Conservative estimation elicits the fact that three hundred thousand of the population of this archipelago are human beings in whom exotic notions do not pertain and in whom are the instincts of the wild animal, and of this number one fifth are to be found on the island of Luzon, the largest and at the same time the most enlightened from ecclesiastic and worldly standpoints.

As all uncivilized human beings have characteristics in common and at the same time many distinctive traits characterize a people surrounded by the same natural environments, to recount these as they pertain to the several tribes is wholly unnecessary. It is sufficient to point out a few of the characteristic features of the more powerful of this class of untamed nomads as they pertain to the Philippines.

Probably the most unrestrained and barbarous Filipinos are the Gaddanes. A race occupying the extreme northwestern end of the archipelago and entirely out of the pale of civilization. They are the only real, war-like people of the North. They know no moral restraint and glory in the shedding of blood. At a certain time of the year, when the so-called fire-tree is in bloom, the young men, as is their custom, go forth on a head hunting expedition and vie with each other in presenting to the sachem of their tribe all the grewsome trophies they are able to take from their enemies, as a

proof of their manliness and courage. The arms used by these people are wicked looking lances with trident tips and arrows carrying at the point a mesh of bats' claws which have previously been dipped in the venom of snakes.

Fig. 2. Gaddanes.

The men are magnificient specimens of physical strength, and with a wealth of long, straight, jet-black hair reaching to the shoulders and with a color of skin of almost equal hue, they make a very striking picture of primitive man. Like the Negrito they subsist on roots, game and such other food stuffs as falls in their path. They are pagans and at no time has any attempt been made to persuade them to embrace the western system of civilization.

Next to the Gaddanes in war-like propensity are the Itaves, a tribe inhabiting the territory just to the south and adjoining that of the head-hunters. Their manners of living and religion are similar to those of the Gaddanes, but they are not so fierce and are more indolent. They are also lighter in color and wear their hair shorter than their neighbors of the north. This tribe is one of the few, if not the only one, which uses the war-club and executes a war-dance preliminary to going into battle.

Fig. 3. Igorrote.

To the American, unquestionably the most interesting people of this class of Filipinos, is the Igorrote, for the reason that they more closely resemble the American Indian in color, configuration and habits than any other tribe of the archipelago. These people dominate the middle north country, where they live in idleness, oblivious of time or conditions. Of all the tribes of the islands they are the acme of physical development. Their chief ethnical characteristics are the high cheek bones, aquiline nose, copper colored skin, long straight black hair cut into a fringe over the forehead, naked save for a breech-clout, and gaudily bedecked with paint, feathers and rings. Unlike the American Indian their lips are thick and large,

and their gait is sluggish and toddling. They, like their brothers of the North subsist upon that which nature is kind enough to cast in their way, however, they do make occasional futile attempts at cultivating a little sugar cane or rice. These people cannot justly be termed a war-like people, yet revenge is one of their strongest traits. Distrust of the white-man is a preëminent feature of this tribe. This fixed dislike is the result of one of the many of Spain's blunders in her sovereignty of these islands, for it was her attempt to force western civilization on these people, who did not wish to exchange the comforts, usages and independence of their primitive state, for what the crown of Spain deemed a proper constituent principle of good colonists. To roam at large in their forest home, free as the wind, was to them more to be desired than to have to wear clothes, pay taxes and incarcerate themselves in the conventional domestic habits of the European. Foreman aptly expresses it when he says "as to Christianity, it would be as hard a task to convince them of what Roman Catholicism deems indispensable for the salvation of the soul as it would be to convert all England to the teachings of Buddha, although Buddhism is as logical a religion as Christianity." The distrust incident to this forcible attempt to civilize and domesticate this people will remain, I believe, one of their prime distinctive characteristics for centuries to come.

There is a hybrid class of Igorrotes, known as the Chino-igorrote. A people differing little from the unmixed blood except that associated with the brutal instincts there is the cunning and astuteness of the Mongol. This mongrel race are supposed to be the descendants of an issue, the result of the affiliation of the dispersed followers of the Corsair Li-ma-hong who attacked the city of Manila and was routed and fled to the region of the Igorrotes. They, like their half brothers, are confirmed infidels.

Of the uncivilized tribes of the north, there are a few who, owing to their distinctive characteristics, are worthy of mention. the principal of which tribes are the Tiñguians, Dayapes, and a peculiar class of tropical inhabitants known as Albinos.

The Tiñguians inhabit principally the district of Al Abra and in appearance closely resemble the Igorrote, and appear to be as intelligent as the ordinary subdued native. They are pagans but have no temples. Their gods are hidden in the cavities of the

mountain fastnesses. These idols are called Anitos and are exhorted when any dire calamity befalls them, and are always appealed to when a child is to be named. In this latter ceremony the priest to the Anito holding the new born in one hand raises a large knife or bolo over its head and upon lowering the blade strikes it into a nearby tree, if the tree emits sap the first name uttered is the one the child will henceforth bear. The oozing of the sap signifies to them the will of the deity. The Tinguians are monogamists and generally are forced by the parent to take a mate before the age of puberty. These people, like the Negritos, live mostly in a baji built in trees, sometimes sixty or seventy feet from the ground. They have a few characteristics akin to the Japanese, principally in the manner of wearing the hair, tuft on the crown of the head, and the custom of blackening the teeth. Their common weapon is the spear, this they use as a matter of defense as well as a means of slaying animals for food.

The Davanese are unquestionably Hindoos and are supposed to be the descendants of the Indian Sepoys, who deserted the British Army when the latter occupied the city of Manila in 1763. They are few in number and occupy principally the district lying about the pueblo of Caintá. These people are semi-civilized, peaceful and to an extent industrious.

There are to be seen among the natives of the north a few of the class of people known as Albinos. These abnormalities of nature present a marble white skin, pink white hair, and pink eyes. They are not associated in tribes or clans but may be found scattered about in most any of the provinces of the north.

Before taking up the analysis of the various domesticated tribes, which go to make up two thirds of the seven million of people who are styled Filipinos, a brief epitome of their early political history is, I believe, essential, as it no doubt has indelibly modified and ultimately formulated the character and customs of these people. We are wont to believe that long before the advent of the Spaniards in this Colony, these islands were visited by the Molaccans, for it was from them that Hernando de Maghallanes, then a Portuguese subject and in the service of his majesty, learned of the existence of these supposed rich possessions in the Pacific, and had it not been for petty jealousies and a weak and arrogant monarch, these same Philippine Islands might have become the possession of Portugal

and not of Spain, as they subsequently became through the public renunciation of Maghallanes to his rights as a Portuguese citizen, and his assumption of the fosterage of Spain, with the result of his entering into a contract with the King of Spain to seek and discover these islands of which he (Maghallanes) had heard. Sufficient to say, that Maghallanes, knighted and invested with the habit of St. James, set sail from the harbor of San Lucor de Boramida, August, 1519, in command of a fleet of five small vessels, which was to figure in history as not only the first to formally discover the Philippine Islands but the first to circumnavigate the globe, thus proving the theory of Aristotle and Ptolemy.

After twenty-one months of privation, scurvy, mutiny and desertion Maghallanes entered the Butan River on the Island of Minhanao, and effecting a landing without any opposition from the natives, took possession in the name of King Charles of Spain, thereby realizing his one ambition to discover those islands which had been his constant dream for years. Thus in part he was recompensed for the bitterness of the past, but he was not decreed by fate to enjoy the fruits of his discovery, as he fell mortally wounded by a poisoned arrow soon after in a conflict with the natives on the island of Magtan. The command of this expedition fell to Duorté de Borbosa, who also met his death soon after at the hands of the natives of the island of Cebú. Juan Corobola, next in command, finding his ships in a leaky condition and crews insufficient in number abandoned all the ships except the Victoria, and returned to Spain, first touching at Borneo and the Molaccas, arriving in the harbor of San Lucor, September 6, 1522. Again in 1542 a second expedition from Spain under Villalobos touched on the island of Luzon. Here, like his predecessors, he met his death. From 1542 to 1564 no more expeditions were sent out by Spain. Finally, on account of the bitter jealousy existing between Spain and Portugal over new acquisitions of territory, another expedition was dispatched by King Philip, under Maguil Lopez de Legaspi, in November, 1564. This expedition encountered even more opposition from the natives than the former ones, and for a period of five years Legaspi was busily engaged forcibly colonizing these people. On the twenty-fourth of June, 1571, the city of Manila was incorporated as the capital city of the archipelago, after a treaty had been consummated with the native Rajahs, Dolumal and Lacaubola.

Soon after this formal acquisition of the islands and the incorporation of its capital, Legaspi returned to Spain where he died, destined like his predecessors to enjoy but little of the honor of having been the first to establish real sovereignty for Spain in this colony.

Spanish suzerainty of the Phillippines was not one long glorious régime, neither were the islands the El Dorado they had fancied, but instead her three hundred years of reign was but a period of almost constant strife. Other nations strove to seize them and rebellion followed rebellion in an effort to expel a sovereign power whose reign was considered unjust, oppressive and tyrannical. In truth, Spanish sovereignty was never complete except in name only, and full domination only extended over the sea-coast towns and a few miles into the interior. Tribal customs governed as many, if not more, of the inhabitants as Spanish laws and Spanish monastics.

The Spanish friar was next installed and, with the aid of the military, set about civilizing and converting to Christianity those tribes lying outside the Capital city.

About this time the island of Luzon was invaded by the Chinese under the notorious pirate Li-ma-hong and the Japanese Sioco. Early on the morning of the thirtieth of November, 1574, they appeared in the bay of Manila and instituted a vigorous attack. After a bloody hand-to-hand conflict the Chinese were completely routed and, not being able to regain their fleet, fled up the coast as far as the Province of Pañgasinan, and it is through the affiliation of these survivors with the natives that we accredit the manifest traces of Chinese blood among some of the hill-tribes to-day.

Following the attempt of the Chinese to seize this Colony the Emperor of Japan, learning of the European colonization, sent one of his suite, Ferranda Kiemon, with a message to the Governor of the islands, demanding prompt surrender and threatening invasion if refused. This, Gomez Perez Dasmarinas, the Governor, refused to do but solicited a treaty of commerce, and expressed a desire to conclude an offensive alliance for mutual protection. The Mikado consented to this proposition and thus for a time amicable relations were assured with the Japanese.

As a result of the war with the Flanders, which terminated with the Treaty of Antwerp in 1619, the Dutch were obliged to seek in

the far east such commodities as they were previously accustomed to obtain on the peninsula, consequently they established trading headquarters in the Molacca islands, and from there preyed upon the Spanish galleons carrying provisions and silver from New Spain to the Philippines. This state of piracy continued until 1645, when the Dutch navy under Admiral Whitier, attacked the city of Manila with twelve men-of-war and was defeated by General Lorenzo Ugarté with great loss, including that of the commander of the fleet.

The period from 1645 to 1719 was one of contention between Church and State, as to prestige in the civil affairs of the colony. This dissention became more marked and the bitter feeling thus engendered finally culminated in one of the most revolting scenes in Philippine history. Little is to be said of this most disgraceful affair other than that a riotous mob led by the priests of the Sacred Orders of San Fancis, San Dominic and Saint Augustine attacked the palace, stabbed and dragged the Governor, Fernando Bustamenté Bustillo y Rúeda, through the streets of Manila, and at the same time killed his son. The mob during their delirium, tore down the Royal Standards and maltreated all those who in any way offended them. A mock investigation was made in due official form but little or no punishment was inflicted on any of the offenders.

Early in 1561 England became involved in a war with Spain through the so-called Family Compact — an alliance formed by the three branches of the House of Bourbon — and this resulted in the city of Havana and many other of the West India ports falling into the hands of the British, and at the same time the sending of a fleet of thirteen ships, under Admiral Carnish, to the Philippine waters. A siege was begun on the twenty-fourth of September with heavy cannonading from the ships and was replied to by the batteries of Fort Santiago and San Andres. At the same time troops, to the number of five thousand, were landed to the south of the city and at once engaged the Spanish allies (about five hundred native Pañgasenans) driving them back in great disorder to the fortified city. This state of siege lasted for fifteen days, during which time General Draper communicated freely with the Acting Governor relative to surrender. The capitulation was finally accomplished on the sixth day of October after great loss of life, and the British flag soon waved over the walls of Fort Santiago.

By the terms of the Pacto de Paris, which reached Manila on the twenty-seventh of August, 1763, the British evacuated the islands, but peace and quiet did not follow. Hardly had the Spanish colors been unfurled ere the natives of Cagayan, Ylocos and Pañgasanan provinces broke out in open rebellion under a religious fanatic Diego de Silan, a half-caste Indian, who declaring the Spanish sovereign a usurper, directed that no more tribute be paid to the Spanish Treasury. This insurrection assumed considerable proportions and not until many lives had been sacrificed and noteworthy concessions made by Spain was peace established.

During this revolt in the north country, the Mussulmans under Datto Teng-teng, attacked the Spanish garrisons on the island of Mindanao, butchering their prisoners and destroying much of the public property. This outbreak was, however, but one of the many reprisals of the Mussulmans as the result of the enforcement of a sovereignty and a religion which was to them nauseous and antágonistic to the Mohammedan faith.

In 1872 occurred what is known as the Cavité insurrection. The real cause of this rebellion was the native opposition to the Spanish friars holding parochial incumbencies contrary to the decision of the Council of Trent. However, the friars claimed to have such authority, by virtue of papal bulls issued by Pius V, wherein they were authorized to act as parish priests where the native clergy were insufficient in numbers. This authority, unfortunately, was abused, doubtless on account of the friars recognizing that full and strict compliance meant monastic impotence politically. This uprising of the natives was promptly suppressed and their leader, José Burgos and his confederates, were duly executed, upon the instigation of the friars, on the Luneta (Manila's famous drive) in accordance with Spanish custom. The moral effect of these executions, however, was but temporary and only served to engender a more bitter feeling against the friars, and at the same time, this one act of Spain's, was the prime factor in the formation of one of the most powerful freemasonries in the world, the Katipunan.

This was the beginning of the end of Spanish rule in the Philippine islands, for it meant the coalescence of all of the tribes, with the common object of expelling a power (the friars) which was not only odious and tyrannical, but dictatorial and to which the Spanish government of the islands was subservient. The cry of

the native was not against Spain as a potentate but against the dominant power of the friars. Spain's avaricious propensity seemed to have subverted her better judgment, and this nation, that at one time was a power potent, was soon to experience the worst insurrection in the history of her Philippine dependency.

She had, by virtue of the Cortes de Cadiz, convened on the twelfth of September, 1809, passed the first Suffrage Bill, which permitted of the assembling of deputies from the various dependencies. For twenty years the people of this colony enjoyed political equality, but finally in 1837, their exclusion was voted as was also the government of the islands by special laws. Spain's mistake was irremediable, the native had tasted of equality and suffrage and he was apprehensive of the motive force back of this repeal and it was this innate contempt for the timorous, so characteristic of this people, and the hatred engendered through the treatment accorded José Burgos that finally culminated in the insurrection of 1896 and '97, the result of which was the sacrifice of many lives, especially that of José Rizal (a story in itself), one of Polaviéjo's most shameful acts, the imprisonment of thousands of suspects in the dungeons of Fort Santiago, who were drowned like rats upon the rising of the tide, the breaking of the treaty of Biac-na-bato and finally the indelible stamp of distrust of the white-man by the native.

With the American occupation and subsequent history, we are all familiar and does not permit of repetition here. From this brief summary of the political history of this colony you will have observed the potent agencies and modifying forces the native has been subjected to for a period of three hundred years and now we can take up the analysis of these people who have been subjected to this environment.

For practical purposes, we will divide the various domesticated tribes into three great classes and endeavor to point out the characteristics of the tribes which dominate the several territorial divisions.

The Tagalog dominates the northern islands, the Visayan, the central group and the Mussulmans, or so-called Moros, the southern islands of the archipelago. There exists no mutual feeling or harmony between these tribes, yet they may unite against a common enemy as in the recent insurrection. The Tagalog and the Visayan

listen to the teachings of the Roman Catholic church, while the Mussulmans are the followers of Mohammed and never during the three hundred years of Spanish sovereignty were they brought under either her religious or political control.

Fig. 4. Tagalog Girl.

The Tagalog as a tribe, numbering about seven hundred thousand, are the most civilized of the three great divisions of the domesticated Filipinos. This is probably due to the fact that ever since the conquest of the islands by the Spaniards, they have been brought in direct contact with Europeans and have felt to an extent the influence of domesticity and social order. The Tagalog and the Visayan differ very little in physique and configuration of

countenance, but their attitude towards strangers (Europeans) is most distinctive. The Tagalog feigns great friendship, while the Visayan is haughty and arrogant. From a physical point of view they both are magnificent specimens of humanity but mentally an anomaly which is most unfathomable. They are about five and one half feet in height, ginger-bread in color, with high cheek bones, flat nose and a wealth of coarse, straight, black hair presenting at all times a lavish amount of cocoanut oil and surmounting a placid countenance.

The innate spontaneity of moral character of these so-called civilized Filipinos is that of half child and half devil. In him we see that puerile lack of objective and simplicity, while beneath that placid countenance and solemn gravity of feature lies deeply rooted all the cruelty, deceit and fiendishness of a demon. He is a profligate and is passionately fond of gambling. This latter foible is gratified in the national sport of cock-fighting and the Spanish game of monté. However, where facilities offer he is a willing tyro to the many and varied gambling devices imported in recent years by the Europeans. He has no sense of appreciation, neither can he comprehend a spontaneous gift, but rather looks upon any form of kindness as an expression of fear or weakness. Honor, in the sense of self respect, dignity, fidelity, virtue or a just discernment of right in strict conformity with duty, is to this most incomprehensible being virtually nil. Magnanimity and chivalry are likewise unknown quantities in the Filipino's composition. He is quick to borrow but slow to return, superstitious to the utmost degree, a natural coward, a brute, and if angered does not readily reveal it in his expression but is most unrelenting, and will await his opportunity for revenge. Unlike the Japanese or Chinese, he is a poor imitator and no originator. Few have any regular vocation, and those few who are endowed with a spirit of self-improvement are only to be found in the large cities. These, moreover, are mostly of the hybrid class, known as mæstizos, and their training is in the arts. The average full-blooded Filipino is well satisfied to trust to the morrow and the munificence of a bountiful nature. He may, out of necessity, cultivate a little patch of rice or sugarcane, but his preference is to sit and dream in the shade of the mango-tree.

Polity and discipline are vague institutions, and Filipino veracity,

excepting the Moro, is but a myth. To lie is but the manifestation of a second nature and to prevaricate with a nicety is an accomplishment with him. The native of this class is so contumacious to all bidding and so averse to social order that, I am inclined to believe, he understands and appreciates no law except force. Sentiment and honor are lost virtues, and there is nothing in which the average male delights more than to pillage and torture. Intuitive modesty is as foreign to the average Filipino as it is to the dumb brutes of the jungle, while the domestic habits of many are very little above their animal surroundings.

Early in the sixteenth century the marriage custom was established among certain tribes through the good offices of the church, and as a result of which nuptial vows are held very sacred, and the husband is extremely jealous of his wife after wedlock, notwithstanding his indifference as to any indiscretion she may have been guilty of before entering the nuptial state. This, I believe, is but a selfish vigilance and not a virtuous sense of chastity, for it is the universal practice with this class of islanders, or at least a large percentage of them and more especially the touis, to barter their daughters. These poor creatures are virtually sold or given in exchange for a loan to pass their youth as queridas (kept-mistresses). As this transfer of human chattel is, in many cases, for the payment of a gambling debt or to secure a loan for some equal moral turpitude, the poor victim not infrequently becomes the permanent vassal of the money-monger.

The cheapest thing in the Philippine archipelago is human life and the dearest object to this oriental's heart is his pet game-cock. He will risk his life many times over to save this idol of the race, while he would tranquilly stand by and see his family in peril rather than expose himself to possible harm in effecting a rescue.

Notwithstanding the Filipino has so many undesirable characteristics, he is not totally devoid of good qualities. Of these I would mention his temperance in the use of alcoholics. During my three years of service on the islands I saw but one native inebriate, yet these same people have liquors more powerful than the worst of moonshine whiskey. Then again there is a certain hospitality existing among themselves which is evinced in the fact that even as an utter stranger they are always welcomed to such food and shelter as may be at hand and no remuneration is expected.

As a people they are musical, although not composers, they are, however, in this latter respect excellent mimics. This inherent musical talent is truly most remarkable, for not only will one find the average native skilled in the playing of one instrument, but it is not uncommon to see orchestral players exchange instruments two and three times during an evening and apparently play the various instruments with equal skill. Go where you will among this great class of Filipinos and every community worthy the name of town, you will find a band of musicians varying from half a dozen to thirty pieces, and even in the isolated mountain districts, where conventional instruments are not obtainable, musicians are to be found playing upon rudely constructed implements made of bamboo of various lengths and calibre. Unlike most Oriental music their melody is pleasing to the European ear.

Among the Tagalogs and Visayans there exists a great mæstiza genera, in consequence of which there is manifested a class of disaffected, arrogant and indolent people, who through appreciation of the superiority of the Caucasian (as a race) have assumed many of his customs, manners and dress, likewise many of his vices but few of his virtues. This mixture of the blood has instilled an increase of energy in some, but it has not obliterated any of the other Malay characteristics in any.

Sunday throughout the archipelago, is the one day of the seven in which the native throws off his state of lethargy and makes ready to enjoy himself. True to his faith, he wends his way to the church at the break of day, this obligation over (for it is more of an inherent duty and superstitious fear with him than a true sense of religious reverence), he straightway directs his steps to the public market place to spend the day in the national sport of cock-fighting. It is here that one gets an exemplification of a Filipino characteristic which but goes to prove the incomprehensible anomalism of these people. By nature they are apprehensive of honesty, yet according to the custom of making a stake on the combatants, the universal practice in vogue, permits any one or any number of persons, even though they be unknown to the keeper of the pit, to throw their money into the arena and keep their own council as to their choice, and should they be successful, can demand their gain and it will be forthcoming without question. No system seems to be practiced to prevent knavishness, and if asked as to this apparent

laxity they simply shrug their shoulders. The Filipino fights his cocks with monté sandwiched between pittings, until mid-day, when he betakes himself to his house for his siesta, and when the sun begins to dip well into the western heavens, he agains seeks the *plaza de gallos*, where he remains reveling in this brutal sport until the last cock has crowed over its fallen adversary. I am wont to believe that the cock-pit is the native's club, his school and not infrequently his only source of revenue.

Probably one of the most uninviting sights in the Colony is the market of the so-called domesticated natives. From the amount of filth and the myriads of flies one wonders little at the various epidemics that so frequently scourge this archipelago. The average Filipino market, of this class, is a combination of hasty lunch, general merchandise and reservoir for all the bacteria known to science. Here doubled up like a jack-knife squats the tribesman with his wares spread out before him on the ground. The barter, even in the city of Manila, is more an exchange of one commodity for another than a purchase through the medium of currency. Fabrics are exchanged for cocoa-nuts, fish for buyo, eggs for tobacco and one of those mysterious native dulcies for personal ornaments. The native is a true Shylock, and it is not uncommon to see two of these tribesmen spend an hour chaffering over some article whose value scarcely exceeds five centavos (two and one half cents).

The buyo and betel-nut are probably the two commodities almost indispensable to the Filipino of the lower class, as well as to many of the elité. He can go a goodly time without food if he but has his buyo. Properly speaking, this is the areca-nut, and which, when cut into small pieces, dusted with the lime produced from the oyster shell, and wrapped in the stripped leaf of the betel tree, is marketed as an individual quid. The buyo is to this Oriental what tobacco is to the European; however, it is by far the more offensive to the æsthetic, in that it stains the teeth and lips a blood-red, exhibiting a condition most repugnant to the eye. The effect of this, when the habit is once acquired, is most disastrous, and in this respect closely allies itself to the results of the use of opium.

Even though buyo plays such a prominent part in the life of these people, everyone is a devoteé to tobacco, men, women and

children, the high and the low, the poor and the rich, priest and layman. The men take to the cigarette, while the women and children prefer the cigar. It is not an uncommon sight to see a child of some three or four years whose only adornment is a long cigar. The cigar is to the Filipino pickaninny apparently what the bottle is to the American youngster, a pacifier.

One may see in their marriage customs another phase of Filipino life which characterizes this class of natives. A sort of purgatorial preliminary exists among these people, in which the vicissitudes of the average native swain are anything but enviable. If poor, and this seems to be the universal state, the prospective groom must serve the girl's parent as a catiped or house servant for a more or less indefinite period, according to their whim, and it is not infrequently the case that after many months, or perchance years, of this bondage, he is turned out and another suitor installed. Again, the marriages are arranged by the parents without consulting the wishes of the child, and quite frequently they are wholly obnoxious to one or both of the contracting persons, and as a result it is not uncommon for the child to force the hand of dictatorial parents by compelling them to countenance his or her legitimate aspirations. Before a marriage is consummated, a dowry is made by the girl's parents in favor of the bride, with the understanding that it is not transferable to the husband upon the death of the wife, but must revert to the parents in the event of there being no offspring (which, however, is rarely the case). In consequence of this it is not uncommon to see the children well provided while the father is a beggar. The day of the wedding is always fixed by the ever vigilant padré and the fee, which is always exhorbitant, is paid in advance, either in currency or collateral. The marriage ceremony of these people is one grand display of barbaric ritualism. Among the very poor class of these so-called domesticated natives, where the enormous fees demanded by the church are beyond their means, the two sexes were accustomed to live together under mutual vows, but since the American occupation marriages by the ecclesiastics is not compulsory, and this practice of mutual assent is fast dying out.

Among some of the pagan tribes, especially the Igorrotes, the marriage ceremony is a sort of a catch if you can affair, in which the prospective groom is led a chase about the village by the bride-to-be, and for a time feigns to catch her, finally he secures his prize

and upon bringing her before her parents, in very much the manner one might lead a reluctant dog at the end of a chain, they bow down and bring their heads together sniff in the air violently (the native substitute for osculation) and receive, at the same time, the parent's sanction which is demonstrated by the pouring of cocoanut oil over their heads. No feast follows as among the Christian tribes but the bridal pair flee to the mountain fastnesses, where they remain for a fortnight subsisting on wild berries and fruits and then return to their native village or clan to take up their abode.

A curious custom which prevails among the more ignorant of the domesticated class of natives, a relic of barbarism, is the practice of closing all the windows and doors of the house and filling every available inch of floor space with the presence of neighbors, during the birth of a child, while the male members of the family thrash about the room, flourishing large knives or *bolos*, like so many mad-men, in their attempt to drive out the evil spirit, as they are wont to believe influences the destiny of the mother. This barbarous practice is carried still farther in some cases by making long gashes through the skin of the *énciente* in the hope that the devil may have an easier exit.

The Filipino funeral is yet another exemplification of the peculiar customs of this type of Oriental. It is a display of fantastic barbarism and blasé sensualism. There is the ghastly bier with its harsh and crude ornaments of wood and metal, a relic of his untutored and savage ancestry. A native band precedes the funeral cortege to the grave, playing some wierd uncanny air followed by a group of professional mourners and the members of the deceased family, exhibiting no signs of grief or regret but an air of stoical indifference, in fact it is not uncommon to see them follow along chatting and smoking as if they were but repairing to some place of jollification. In the large cities, this burial custom is somewhat modified by the introduction of a tawdry bier on wheels and drawn by four or more horses, with footmen and runners dressed in the garb of the sixteenth century courtier, the whole rendering this solemn procession ludicrous and insensate. Upon reaching the burial ground the corpse is stripped and wrapped in a piece of *sáula* or matting, and without further ceremony deposited in a vault or grave until such time as the rental expires, when, if not renewed, it is resurrected and thrown to bleach under a tropical sun, with

hundreds of others, unclaimed and forgotten, upon the so-called bone-pile. Every necropolis has its bone-pile. It is an institution of the church and like the potters-field is the final resting place for many a departed being destitute of friends or kin.

Sunday in the Philippines, as in all Spanish countries, is the great theater day and all the large towns of the islands have their various play-houses. The dramatic composition is always in the native dialect and usually melo-dramatic in character. To the European the plays are highly ludicrous and extremely tiresome, as the several parts are not memorized by the actors but are repeated after a prompter, who is seated in front of the stage and not infrequently in full view of the audience. The plot is always some supposed conflict of times past between the Mohammedans of the south and the early Christians. There is much palavering with painful attempts at oratory and brandishing of knives. Then comes the bloody conflict, the wild beast of the forest puts in its appearance, the ghost walks and the curtain is finally drawn amidst the loud applause of the audience. These plays, like those of the Chinese, not infrequently run for days before the climax is reached and the plot unraveled.

The matter of bathing practiced by this beople is worthy of mention. Notwithstanding the filth of the average native's house and the unsanitary surroundings these same people may be seen each morning bathing in the waters of a nearby stream. If this is not accessible they will find a pool in which to bathe, even should this pool be nothing more or less than a composite of all manner of filth. He must take his daily bath no matter in what or with what and not infrequently this latter resolves itself into nothing more than a bowl of water and a gourd for a dipper. His bath like his siesta is, I believe, more a habit than a sanitary necessity in the eyes of this people. Men and women bathe together and with little or no respect for modesty. How about in America? Living in public! In Camarines and that what hap

Author is unf[illegible] Too much prejudice. Lacks sympathy or understanding about the real life of the people [illegible]

The Filipino, as a people, wash their linen as do the East Indians by beating them with a pamalo upon the rocks. Needless to say the clothing suffers no little in consequence of this treatment.

Being naturally prone to superstitious beliefs the early native accepted all the fantastic tales of the early missionaries, and the modified heathen rites adopted by the Church were received will-

ingly by them. He loved the pompous ritual, the gaudy and elaborate robes, the glitter of gold and silver and the images of saints. All these appealed to his savage nature and his ancient tribal legends, and this ocular demonstration seems to have impressed him with the sanctity of the system and the infallibility of its believers. The result is, that to-day, shrines are to be found in almost every semblance of a town throughout the islands where the faithful Filipino comes at least once a year to worship.

There seems to be no limit to the number of saints, there is the patron saint of the islands, Santa Rosario, and the innumerable local saints whose images are revered and worshipped for some wonderful mystic power of healing the sick and halt or some marvelous act they are supposed to have performed in the dim past. The victory over the Chinese, during the invasion of Li-ma-hong, is accredited by the natives to the appearance of Saint Francis on the walls of the city. The legend of the celestial protector of Manila is not less interesting. It is related that in Dilo, near Manila, a wooden image of St. Francis de Assisi was seen to weep so copiously that many cloths were moistened by its tears, and again this same image with its hands uplifted and opened during three hours asked God's blessing on the city of Manila, then closing its hands it grasped a cross and skull so firmly that these appeared to be one and the same thing. Vows were made to this saint, who was then declared protector of the capital. Others of equal significance might be mentioned but this will suffice to show the innate mysticism of these people. Many of these images are most tawdry and elaborately ornamented. I believe the most elaborate I have seen, outside of the metropolis, was in the town of Quingua, province of Bulican. The image was that of a man astride a horse and attired in a gorgeous robe. In his uplifted hand he held a dangerous looking knife and under his prancing steed lay the prostrated form of a Mussulman, bleeding and wounded unto death. This was mounted on an elevated carriage, and strung about the platform were the heads made of carved wood, mutilated in appearance, representing the many victims of this venerated saint. The whole was a barbarous display of cruelty and superstition.

The roguery of the Filipino is not infrequently manifested through the agency of these saintly images, and it was only within

the past few years this was brought to the American public's notice through an unjust attack upon the army in permitting the supposed looting of one of the churches of the Colony and bringing into the states one of these sacred images. Upon investigation this "Black Christ," over which the stir was raised, proved to be a private institution of some scheming natives working upon the superstition of their people to extort money for personal gain. The image was an exquisitely carved piece of wood, waxed and stained to a deep brown, while the eyes were of glass and framed with eyelids most human, and the whole enveloped in rich drapery. With the aid of a ventriloquist (José Zaide) the natives were led to believe that this "Black Christ" was the new Messiah through whom their sole redemption from the torments of hell could only be obtained by the making of large donations of money.

Other superstitious beliefs might be mentioned, such as the diabolical influence supposed to be possessed by certain persons which preserves them from all harm even refractory to the effect of bullets, called the *anting-anting*. Then again the belief held by many, that a crime escapes punishment if committed in Easté week, because the thief on the cross was pardoned of his sins, and many more might be enumerated if but time permitted.

Before taking up the third great classification of these domesticated natives, I wish to make mere mention of the sport of hunting the wild-buffalo and boar much engaged in by these people and the bull fights, which until 1885 obtained throughout the principal cities of this dependency. Likewise a brief description of this freemasonry that exists on the islands, the so-called Katipunan. This is a Tagalog word the meaning of which is league. The organization was originally perfected with the object of retribution and was the result of the confederation of the various dissatisfied islanders under the leadership of one Andres Bonifacio, a native half caste, who drew up its constitution and devised its mystic rites, which were of a dread and impressive character, breathing vengeance upon Spain and more especially the monastics. Since the end of Spanish rule in the archipelago the Katipunan has been felt not a little by the American forces operating in the islands, and it must be admitted that it is a powerful agent in the political prosperity of this Colony. In 1896 there was known to have been at least fifty thousand leaguers and by 1900 this number was trebled.

As regards this third division of the domesticated Filipino, the so-called Moros, I can say but little and that principally from the observation of others, as it has never been my lot to have been thrown in contact with these people as a collective body. These people occupy the islands of Mindanao, Palawan and the Sulu

Fig. 5. Mussulman Girl, "so-called Moro."

sultanate. Their early history is vague and dissipated. It is generally conceded, however, that these people are the descendants of the Mussulman Dyaks of Borneo, their ancestors having been a great chief and his retinue, who early in the sixteenth century fled his native land and settled on these islands, bringing with them the Mohammedan faith. This strange people never yielded to either Spanish arms or Spanish monastics, but continued

throughout Spain's regimé to rule by tribal custom under the direction of a Datto or chief and recognizing only the spiritual supremacy of the Sultan, whose position is hereditary under the Salic law and who annually makes his trip to Mecca.

The Mussulmans are a valiant and merciless people and for centuries they controlled the high seas in that part of the world, ravishing the coasts in their piratical workings. It was not until the introduction of steam vessels that Spain was able to cope with these robbers of the seas. The Moro is very much averse to work, consequently he is not an agriculturist. His whole ambition in life seemingly is to strut about in gaudy attire, and encased in a veritable arsenal of knives, etc.

Slavery exists in an occult sense among these people. There are slaves by birth and slaves by conquest, such as insolvent debtors and prisoners of war. Unlike the other tribes of the islands the veracity of these people is not to be questioned, for to lie with them is a heinous crime and deserving of severe punishment, the penalty of which is usually the severing of the tongue or splitting the mouth.

Until 1902 these people gave the United States authorities no trouble but the moment their ancient rights, customs and religion were supposed to have been interfered with, it was the stirring up of a hornet's nest.

Many other characteristics might be enumerated if but time permitted, however, this will suffice to show the character of these people as we see them to-day.

Philippine condition today is entirely
different from what Metzger saw in 1905.

etzer went to P.I. not as a broadminded ~~man~~
but on the other hand he went there ~~with~~
as a fault finder. In fact no broadminded
reader or any american who has been in the
P.I. who really did understand the Filipinos and
who really knows who he is talking about woul
not only Laugh at him, sneer at him, and
perhaps Curse him, but also would gladly
Brand him as the most Perfect Liar
the world has ever produced. Worthy reade
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SOCIOLOGY OF THE ABORIGINES OF WESTERN AUSTRALIA.

R. H. MATHEWS, L.S.

(*Read March 17, 1905.*)

Five years ago I communicated an article to the Society,[1] dealing with some of the customs of the natives of Western Australia. On that occasion I described the organization of a number of tribes possessing four divisions in their social structure. In the present paper it is proposed to give a short explanation of a different organization, found among some tribes occupying the northeastern corner of Western Australia, comprising the country drained by the sources of the Ord, Denham, King and other rivers, Stirling Creek, Sturt Creek, Margaret River and the Upper Fitzroy. Some of the best known of the aboriginal tribes within the immense geographic limits mentioned, are the Lunga, Kityu, Charrau and Nining.

All the details given in this article have been gathered by me through the kind assistance of correspondents who reside in the Kimberly district of Western Australia, in the region inhabited by the tribes treated of. I sent them categorical lists of all the points upon which I wanted information and gave them directions how to proceed with the investigations. From the reliable character of my correspondents, and my own general knowledge of the subject, I feel sure that their work can be depended upon. It is unnecessary to add that I am under no obligations to any other authors.

A whole tribe, or it may be a community of several tribes, is nominally divided into two portions, which may be called phratries, groups, or any other distinguishing title. Next there is a repartition of each phratry into four parts, which for purposes of reference, may be called sections or classes. A name is given to each section, by means of which the members of the different divisions are readily distinguished; and identification is further facilitated by a masculine and feminine form of every one of the eight names.

A phratry therefore contains four given sections of men, who

[1] "Native Tribes of Western Australia," PROC. AMER. PHILOS. SOC., Vol. XXXIX, pp. 123-125.

marry certain four sections of women. In other words, the men of one phratry marry the daughters of the men of the other, in a certain fixed rotation. The constitution of the phratries, the nomenclature of the sections, with the order of intermarriage and the designation of the children, will be readily understood by an examination of the following tabular synopsis:

TABLE I.

Phratry.	Father.	Mother.	Son.	Daughter.
A	Changura	Nungulla	Chabuldyi	Nabicherri
	Chanima	Nulima	Chungarin	Nabungarti
	Chungulla	Nangilli	Chambin	Nambin
	Chulima	Nabana	Chakara	Nakara
B	Chakara	Nabicherri	Chulima	Nulima
	Chambin	Nabungarti	Chungulla	Nungulla
	Chungarin	Nambin	Chanima	Nabana
	Chabuldyi	Nakara	Changura	Nangilli

The above table gives the phratry, father, mother, son and daughter on the same line across the page. For example, Changura takes a Nungulla as his wife, which is the ordinary or normal rule of marriage and may be called "No. 1." He could instead marry a Nulima, which I shall designate as "No. 2." Or he could mate with a Nabana woman as "No. 3." And lastly, he may espouse a Nangilli, who can be distinguished as "No. 4." Marriages of the "No. 1" type, which are those given in the table, are the most usual; "No. 2" is the next most in favor; whilst "No. 3" and "No. 4" are more or less uncommon, although quite lawful.

In the tribes we are now discussing the section to which the children belong, and consequently the phratry also, is invariably determined through the women. Taking an example from phratry A in Table I: If Changura wed a Nungulla, as in the table, his children will be Chabuldyi and Nabicherri; if he take a Nulima spouse, they will be Chungarin and Nabungarti; if he choose a Nabana, the offspring will be Chakara and Nakara; and if his wife be a Nangilli, then his family will be Chambin and Nambin.

We will now show the wives eligible to Chanima, the next name in Table I. He marries Nulima as his tabular wife or "No. 1"; he takes Nungulla as his alternative spouse, or "No. 2"; he mates with Nangilli as "No. 3," and he can marry a Nabana woman as

"No. 4." Similarly Chungulla and Chulima can marry either of the women opposite their names in the table as "No. 1" and "No. 2" wives; or they can take Nulima or Nungulla as their "No. 3" and "No. 4."

It appears, then, that any specific man in Phratry A can marry any one of the four women opposite to him in the column headed "mother" in the table. Everything which has been said respecting the marriages in Phratry A applies equally to the marriages of the men and women in Phratry B.

All the people have totems, consisting of animals, plants, the elements, and so on, but there is no well established descent of any given totem from the parents to their offspring. Indeed, there could not be any regular succession of the totems in a tribe where the intermarrying laws are as stated in Table I. For example, if descent were through the males, and Changura's totem were a bandicoot, it would not only be liable to be disseminated through the children of any or all the sections in Phratry A, but in the next generation it would be similarly distributed to the children of all the men in Phratry B. Hence, in a tribe where the sociology is so constituted, we discover that in some cases the totems follow the father, in others the mother, and again in other instances the children inherit the totem of neither parent. The totem of the offspring is determined by the old men in accordance with customary laws, which need not now be entered upon.

Space will not permit of a genealogical tree, but the reader can easily construct one for himself from the following explanation. A study of Table I discloses that Chabuldyi, the first name in the "son" column, has a normal or "tabular" father, Changura. But he may have what we shall distinguish as an "alternative" father. Of these "alternative" fathers Chanima is the most general, whilst Chungulla and Chulima are not so frequent.

Looking at Table I, we see that Changura's father is Chabuldyi, and the latter's father is Changura. That is, Changura's paternal grandfather is Changura, the same as himself. Then Changura marries his father's "tabular" father's sister's son's daughter Nungulla, as "No. 1" wife already described. Or he marries his father's "tabular" father's sister's daughter's daughter Nabana as "No. 3." Again, Changura may espouse his father's "alternative" father's sister's son's daughter Nulima for "No. 2." Or he can take his father's "alternative" father's sister's daughter's daughter Nangilli as his "No. 4" wife.

The genealogy of Changura's wives could likewise be traced through his mother's father. A woman ascertains who are her potential husbands by going back to her mother's "tabular" father, or her mothers "alternative" father, as well as her father's father, from which point the pedigree is the same in principle as that of last paragraph. It is manifest, therefore, that whichever one of the four specific women which a man is allowed to take as a wife, possesses practically the same relationship to him, although through different channels. The lineage from which a man obtains his wife is decided by the elders of the tribe.

PARRAMATTA, NEW SOUTH WALES.
February, 1905.

Stated Meeting, April 7, 1905.

President SMITH in the Chair.

A letter was read from Mr. James Douglas describing a so-called shower of toads which he saw in the Sulphur Spring Valley, Arizona, and confirming the observations of Dr. C. C. Abbott (see these PROCEEDINGS, Vol. XLIII, p. 163).

The decease was announced of the following members:

Henri Louis Fréderic de Saussure, at Geneva, Switzerland, on February 20, 1905, æt. 75.

F. A. Randall, M.D., at Warren, Pa., on January 23, 1905.

Dr. Alexander C. Abbott read a paper on "Epidemic Cerebro-Spinal Meningitis."

General Meeting, April 12, 13, and 14, 1905.
April 12,

Afternoon Session.

President SMITH in the Chair.

The President opened the meeting with a brief address of welcome.

An invitation was received from the Naturwissenschaftliche Verein für Schleswig-Holstein to be represented at the cele-

bration of the Fiftieth Anniversary of its foundation to be held at Kiel on June 17 and 18 next. On motion, the President was authorized to appoint delegates.

The following papers were read:

"The Weal-Relation," by Prof. Lindley M. Keasbey, of Bryn Mawr, Pa.

"A Plea for Governmental Supervision of Posts Necessitating Normal Perception of Color," by Dr. Charles A. Oliver, of Philadelphia.

"The Present Status of the International Catalogue of Scientific Literature," by Dr. Cyrus Adler, of Washington.

"The Composite Character of the Babylonian Creation Story," by Prof. Morris Jastrow, Jr., of Philadelphia.

"The English Masque," by Prof. Felix E. Schelling, of Philadelphia.

"The Emancipation of the Waterways," by Prof. Lewis M. Haupt, of Philadelphia.

"The Beginnings of Lumbering as an Industry in the New World," by Mr. John E. Hobbs, of North Berwick, Maine.

April 13,

Morning Session.

President SMITH in the Chair.

The following papers were read:

"The Structure of the Lignified Cell Wall," by Prof. John M. Macfarlane, of Lansdowne, Pa.

"New Species of Genus Nepenthes," by Prof. John M. Macfarlane, of Lansdowne, Pa.

"On Thought Transference Among Animals by Touch and Scent," by Mr. Alden Sampson, of Haverford.

"Mosaic Development in Ascidian Eggs," by Prof. Edwin G. Conklin, of Philadelphia.

"The Oligodynamic Action of Copper on Some Intestinal Organisms," by Prof. Henry Kraemer, of Philadelphia.

"Observations on Columbium and Tantalum," by Dr. Edgar F. Smith, of Philadelphia.

"The Effects Upon Metabolism of Preservatives Added to Foods," by Dr. Harvey W. Wiley, of Washington.

"The Use of the Rotating Anode and Mercury Cathode in Electro-Analysis," by Lily G. Kollock and Dr. Edgar F. Smith, of Philadelphia.

Afternoon Session.

Vice-President SCOTT in the Chair.

The following papers were read:

"The Rounded Sands of Palæozoic Formations," by Mr. Gilbert van Ingen, of Princeton.

"A Review of Lacroix's Work on the Montagne Pelée," by Prof. Angelo Heilprin, of Philadelphia.

"Notes on the Genus Sinopa," by Dr. W. D. Matthew, of Princeton.

"The Mammalian Fauna of the Fort Union Beds," by Mr. M. S. Farr, of Princeton.

"The Marsupial Fauna of the Santa Cruz Beds," by Mr. W. J. Sinclair, of Princeton.

"The Mutual Affinities of the Species of the Genus Cambarus," by Dr. A. E. Ortmann, of Pittsburgh.

"The Faunal Relations of the Ryu-kyu (Loo Choo) Islands," by Dr. Henry A. Pilsbry, of Philadelphia.

Evening Session.

Prof. Russell H. Chittenden, of New Haven, read a paper on "Reason and Intelligence *vs.* Custom and Habit in the Nutrition of the Body."

April 14,

Morning Session.

Vice-President NEWCOMB in the Chair.

The following papers were read:

"The Secular Perturbations of the Earth," by Mr. Eric Doolittle, of Upper Darby, Pa.

"On the Problem of Four Bodies," by Prof. Edgar Odell Lovett, of Princeton.

"Radio-Activity in Solar Phenomena," by Prof. Monroe B. Snyder, of Philadelphia.

"Evidence Relating to Latitude Variations of Short Periods. From Observations at the Flower Observatory During the Year 1904," by Prof. C. L. Doolittle, of Philadelphia.

"Enquiry Into the Pressure and Rainfall Conditions of the Trades-Monsoon Area, by W. L. Dallas, of the Meteorological Office, India.

"On the Construction of Isobaric Charts for Upper Levels and Their Dynamic Importance in Dynamic Meteorology," by Dr. J. W. Sandström, of Stockholm.

"The Straight Line Concept," by Prof. P. A. Lambert, of Bethlehem, Pa.

Executive Session.

President SMITH in the Chair.

The pending nominations for membership were read and the Society proceeded to an election.

Afternoon Session.

President SMITH in the Chair.

The Tellers of Election reported that the following candidates had been elected to membership:

Residents of the United States:

Joseph S. Ames, Ph.D., Baltimore;
Thomas Chrowder Chamberlin, Ph.D., LL.D., Chicago;
William Gilson Farlow, Cambridge;
Charles H. Frazier, M.D., Philadelphia;
David Starr Jordan, Stanford University, Cal.;
George Lyman Kittredge, LL.D., Cambridge;
Robert G. Le Conte, M.D., Philadelphia;
Eliakim Hastings Moore, Chicago;
George T. Moore, Ph.D., Washington;
Richard A. F. Penrose, Jr., Ph.D., Philadelphia;

Francis P. Venable, Ph.D., LL.D., Chapel Hill, N. C.;

J. Edward Whitfield, Philadelphia;

Bailey Willis, E.M., C.E., Washington.

Foreign Residents:

Yves Delage, Paris;

Otto Nordenskjöld, Stockholm;

William Matthew Flinders-Petrie, D.C.L., LL.D., F.R.S., London;

Edward Sievers, Leipzig;

Sir William Turner Thiselton-Dyer, LL.D., Ph.D., F.R.S., Kew, England.

The following papers were read:

"On the Theory of the Double Suspension Pendulum," by Prof. Robert S. Woodward, of New York.

"The Relation between the Economic Depth of a Bridge Truss and the Depth Which Gives Greatest Stiffness," by Prof. Mansfield Merriman, of South Bethlehem, Pa.

"On the Dispersion, Absorption, Fluorescence and Magnetic Rotation of Sodium Vapor," by Prof. Robert Williams Wood, of Baltimore.

"On a Possible Case of Scattering of the Ultra-Violet Light by Gas Molecules," by Prof. Robert Williams Wood, of Baltimore.

"The Use of the Falling Plate Oscillograph as a Phase Meter," Dr. William McClellan, of Philadelphia.

"On the Brains of Scymnus, Mitsukurina and Chlamydoselachus, with Remarks Upon Selachian Brains from Standpoints Morphic, Ontogenic, Taxonomic, Phylogenic and Pedagogic," by Prof. Burt G. Wilder, of Ithaca.

A PLEA FOR GOVERNMENTAL SUPERVISION OF POSTS NECESSITATING NORMAL PERCEPTION OF COLOR.

BY CHARLES A. OLIVER, A.M., M.D.

(Read April 12, 1905.)

When it is realized how important becomes normal perception of color in situations in which accurate color-vision is one of the main requisites or the sole determining factor for the safety of lives and the protection of property, it will be at once understood that definite rules for the obtainance of color-material, the construction of test and governing objects, and the choice of standards of necessary color-sense, should all be placed under the supervision of a controlling body from whom all requisite laws shall proceed, all regulations exercised, and all appeals of enforcement made.

Arbitrary selection of color-material, even though scientifically and properly obtained primarily; voluntary employment of necessarily many empirical — and hence ofttimes, imperfect — methods; and the existence of multitudinous controlling corporate bodies for the adjudication of uncertainties, neglect, and intentional wilful acts — must all exist — as they practically now do — just as long as no steps are taken to place the entire question under the supervision of a national governing board.

Railway service, no matter what the form of motor may be or in what manner the necessary duties are performed, is mainly governed during actual work by the proper and ready recognition of color-signals which are placed sufficiently distant for safety to those for whom the signalling is intended; naval and marine transport throughout the world is mostly accomplished amid its many vicissitudes of atmospheric and hydrostatic change, by quick and certain detections of chosen peculiarities of color situated at safe points of definite signification; and army signalling and geodetic survey work in their every varying degrees of necessity of occasion, are largely dependent for success upon both aided and unaided color vision. These conditions granted, it will be at once seen how vast the field of color employment is, how necessary that proper material shall be correctly used, and how important it becomes that the perfor-

mance of the actual work shall be limited to those who possess normal color-vision.

The facts set forth in this brief communication once recognized and systematically applied, thousands of lives must be annually protected and millions of property yearly saved; a result for which this plea — a most urgent one — is offered; a plea which demands that in this country — these United States of America — there shall be established a board of authority composed of those who are best suited for the establishment and the continued furtherance of the required work performed, meeting in association with representatives from the variously affected departments of state.

EMANCIPATION OF THE WATERWAYS.

BY LEWIS M. HAUPT.

(Read April 12, 1905.)

Probably no expenditure made by the Government produces a larger return than that for the development of our waterways. They are the lines of least resistance but in a state of nature they are not always available. Their economic possibilities are inestimable, when not obstructed by bars or tolls. By the improvement of the channels connecting the Great Lakes to a depth of 20 feet, not only has the cost of the transportation been greatly reduced but the enormous stimulus given to manufacturers has added largely to the population and wealth of the cities encircling these waters. Thus the rate on a bushel of wheat from Chicago to New York by the Lakes and Erie Canal, in 1866, when the Sault Canal depth was limited to 12 feet, was 29.62 cents, whereas the rate on a 20-foot draught in 1904, was only 4.71 cents, or only about one sixth, thus effecting a saving of 84 per cent. The rail charges between the same terminals were, for the year 1866, 32.79 cents, and in 1904, 11.11 cents showing a reduction of about two thirds in the charges by rail. From these significant figures it appears that while the charges by rail and water had both been greatly reduced, in 1866 the water charge was 90 per cent. of that by rail while in 1904 it was only 42 per cent.

But a still more impressive illustration as to the beneficial effects of this improvement is set forth by the statement made in 1892 by Senator Wm. P. Frye, in presenting his committee report, wherein he said that for the year 1890 "The total expenditure for water improvements of the lakes has amounted to about $30,000,000, or approximately one fifth of the annual saving effected in transportation. . . . Our waterways have acted as the most powerful regulators of rates. . . . When it is considered that a diminution of one mill per ton on the railroads of the country effects a saving of nearly $100,000,000 to the shippers in transportation, the value of this restrictive power cannot be overestimated." Had the distinguished Senator added as a recognized fact that such regulation by water does not reduce, but greatly increases the revenues of the

railroads he would but have emphasized the Commercial Paradox, which comparatively few persons appear to recognize.

In 1890 the unit rate by rail was about 9 mills and by the lakes alone was 1.2 so that the computed saving on the tonnage moved by water that year was $147,027,514. Applying the same method to the tonnage and rates of 1903 it is found that the water rate is about 6.7 mills less that that by rail while the total ton-mileage of the lakes is 28,974,660,408 so that the economy effected for the year 1903 is about $194,139,206. Attention is directed to another impressive result of the deepening and enlargement of the capacity of the channels, in the greatly increased size, tonnage and economy of operation of the vessels engaged in this traffic. Thus from 1855 to 1883, or during the 26 years when the draught was limited to 12 feet the traffic increased from 106,296 to 2,042,259 registered tons, giving an average increment of 56,918 tons per annum. From 1883 to 1896, when the Weitzel-Lock was in operation, with its 16 feet depth, the annual increment was 935,211 tons and after the opening of the great Poe-Lock in 1896 it immediately expanded to 2,750,000 tons so that the registered tonnage in 1902 reached the unprecedented total of 31,955,582, in the seven months of open navigation. Again the value of land is effected by its earning capacity as measured by the price of its products on the spot and this in turn is a function of the cost reaching the ultimate consumer.

Thus the effects of the cheaper water routes manifests itself most remarkably, as will be seen by reference to the average values of the farm products of the several states as furnished by the Department of Agriculture. From the statistics covering a decade, it is found that the lowest average price for wheat is in Nebraska and that it increases in value as the seaboard is approached. The difference in price between the 50.9 cents per bushel in Nebraska and the 78 cents at New York, 1,214 miles distant, is 27.1 cents per bushel or $8.94 per ton which gives 7.2 mills for the ton-mile rate which is just the average for the United States, so that the price on the farm in Nebraska is regulated by that at the port of export, less the freight charges.

In Missouri where wheat may be shipped by the Mississippi river to New Orleans from St. Louis, 1,162 miles for 4.88 cents per bushel or $1.61 per ton the rate becomes only 1.4 mills by water.

If sent to New York by rail, 946 miles, it is 6 mills per ton-mile. In consequence of this possible competition therefore the average price paid to the Missouri farmer is ten cents a bushel higher than that paid in Nebraska and this at 12 bushels to the acre means a net return of $1.20 per acre on his crop.

Extending this analysis to the cereals of the two adjacent states of Kansas and Nebraska the former having the advantage of greater proximity to the waterways, for the year 1901 it was found that the five cents higher price realized on the wheat crop, gave to Kansas $4,953,965 greater revenue than her neighbor, while at nine cents more per bushel on corn her advantage was $5,535,543 and for oats at six cents, it was $1,039,944, making a total of $11,530,000 on these three cereals. In the same manner it is found that if Nebraska could have marketed her grain at Kansas prices she would have received $14,267,000 more, in one year. The total expenditures on the rivers and harbors of the country up to September 19, 1900, is reported to have been $370,411,124.44, 4 per cent. of which would represent the annual loss to one state due to the absence of water competition.

THE POLICY OF OTHER COUNTRIES.

It is not surprising therefore that in the sagacious French Republic which has expended over $700,000,000 on her internal waterways, which are free of tolls, her economists believe this policy to be fully justified by the indirect returns and the thrift and prosperity of the people incidental thereto.

So too the Dominion of Canada has not hesitated to provide the munificent sum of $95,316,910.07 for her system of internal waterways, which have returned only about one eighth of this sum, yet the Government recognizes "that waterways and roadways are essential to the commercial life of the country."

Great Britain has learned from a sad experience that the purchase of 1,138 miles out of a total of 3,906, by the railroads, up to 1883, has so retarded her trade that she is no longer able to compete successfully with her foreign rivals and Parliament had prohibited the further control of the waterways by hostile interests and is returning to the policy of rehabilitating them under corporate management. Moreover it is shown that the 2,768 miles under independent control, in 1898, earned a net profit of $1,080

per mile while the returns from the 1,138 miles, managed by the railroads, only averaged $200 per mile. To secure the rights and privileges of an open port the Manchester district contested for enabling legislation for five years at a cost of $750,000 against the allied interests of the railroads and the port of Liverpool but now that the great work is completed, at a cost of about $75,000,000 the 13,000 vacant dwellings and factories are filled and as many more have been added to the district, while the interests formerly opposed, on principle, are all doing a much larger business than before.

Belgium, but little larger than Vermont, has 1,300 miles of waterways of which the center is Antwerp. Notwithstanding the fact that the State owns most of the railways it has encouraged the construction of the canals so as to render the transportation "as cheap as possible, that by this means the Belgian manufacturer may be enabled to compete on most advantageous terms with his foreign rivals." During the last 25 years about $90,000,000 have been spent on ports and canals, so that goods can be carried in 300-ton barges directly from the factory to the ship and by the economies thus effected the manufacturer can underbid his foreign competitor.

Germany is building an extensive system of canals to connect the Rhine with the Vistula, passing through her national capital. Russia is urging a thousand-mile canal to unite the Baltic and Black seas. France is proposing further extensions to her ample facilities and intends making a sea-port of Paris. Austria and Italy are also expending large sums for the benefit of their trade with foreign countries and yet the astute American who is on the alert for the best and most economic administration apparently fails to appreciate the great utilities and possibilities lying almost in a state of nature, at his very doors.

POLICY OF THE UNITED STATES.

As evidence it is necessary to refer to the condition of the canals of this country to-day as compared with those of the past century. Massachusetts claims the honor of building the first canal around the falls of the Connecticut in 1792–3 and the first railroad at Quincy in 1827, 34 years later. During this period a large number of canals were incorporated to connect navigable waters, and the discovery of hard coal in Eastern Pennsylvania in 1792 also

stimulated the opening of canal routes to the great cities of the seaboard and for its transportation to the manufactories. Thus the Delaware and Hudson, the Morris and Essex, the Schuylkill Navigation, the Chesapeake and Ohio, the Delaware and Raritan, as well as the James River and Kanawa, the Pennsylvania, the Schuylkill & Susquehanna and the Erie were well under way or completed prior to the advent of railroads; but it soon after became apparent that a railroad constructed by private capital could not conduct a profitable business as a competitor of a free waterway built and operated by public funds, so that a war of extermination began between these interests and it became necessary to purchase or lease the canals to control their tonnage. Instead of enlarging and modernizing them for the interest of the lessees and the public they have in some cases been abandoned and in others only sufficient traffic is carried to maintain the charters. The result of this policy is well illustrated in the history of the State works of Pennsylvania where between 1865 and 1874 some 701 miles of canals, which had cost over $33,000,000 to build, were abandoned. In a similar way 656 miles of the Ohio canals were obliterated having cost nearly $11,000,000. New York has been more fortunate in having lost only about 269 miles which cost something over $10,000,000, but the determined effort now making to prevent the enlargement of the Erie Canal to even 12 feet depth indicates that the active opponents to our waterways are not yet convinced that their best interests are conserved by these great arteries of cheap transportation. The beneficial effects of the cheapest water competion in the country upon railroad interests may be seen along the Great Lakes where the roads skirting their banks are amongst the best revenue producers in the United States. If it were possible to purchase the 90,000 square miles of non-productive water-surface and convert it into arable land the railroad interests would not permit it to be done as it would exterminate the prosperous cities and industries which these waters have created, and ruin the tonnage incidental thereto, yet they persist in obstructing deep water legislation. By the end of 1835 there were about 2,700 miles of canals open and in use and only about 1,000 miles of railroad; in 1889 the canal mileage had fallen to 2,305.2 while the railroad mileage had increased to 157,976 miles and to-day it is not less than 212,000. Of the canal mileage only 40.6 is under the con-

trol of the general Government and 2,264.6 is under State or corporate control. This does not include the 1,078 miles of slackwater river improvement, making in all only about 3,400 miles for the entire internal water-borne commerce of the United States.

What this indifference to the earning capacity of canals means in the cost of wear and tear, for maintenance, may be well exemplified by a comparison of the reports of the United Railroads of New Jersey for the best year of the canal traffic before it was leased by the railroad, and when its traffic reached nearly 4,000,000 tons per annum.

In the reports of the company for the year 1866 it is stated:

The cost of the Camden and Amboy R. R. and its equipment......	$10,099,000
The cost of the canal and appurtenances............................	4,381,251
The cost of operating the railroad for the year was......................	3,801,732
The cost of operating the canal for the same period.....................	360,513
The net revenues from the railroad were..................................	511,162
The net revenues from the canal were......................................	933,642

So that the railroad returned a little more than five per cent. while the canal earned nearly twenty-three and the operating expenses were less than one tenth of the former. This financial statement is independent of the general benefit conferred upon the public at large by the lower charge for freight carried.

From the above statements as to the great economic advantages of canals, the neglected condition of our own and the activity shown in foreign countries which are thoroughly alive to their importance, it would seem incredible that this government has failed so frequently to act upon or authorize others to engage in most laudable projects, which call for no appropriations from the general treasury for construction, and that petitions of influential communities and large industrial centers are set aside on the score of economy or for other pretexts so that these most important economies in interstate traffic are prevented from securing legislation for periods varying from ten to twenty or more years. Some of the most worthy projects have been before Congress for nearly a half century and do not appear to be much nearer fruition than when they were first proposed.

THE OHIO RIVER.

The largest manufacturing district in the world, that at Pittsburgh, has been praying Congress for a charter to construct a ship

canal to connect the Ohio river at Beaver with Lake Erie at Ashtabula, so that the congestion of the trade in coal, iron and steel may be raised and the price of these commodities be reduced, but in vain. In this district the annual tonnage now exceeds 86,-000,000 which is greater than that of any port in the world, and the great rivers leading to the sea are not yet navigable for boats of even six feet draught. They must wait for floods to float them to the markets. What this means may be best shown by the experience of the season of 1895 when the coal which had been accumulating from April 18 until November 28, seven months, and which amounted to 1,200,000 tons was providentially released by a flood only in time to prevent it being frozen in and a large part of it lost. As it was, the cost of keeping the barges afloat amounted to $2,000 a day. The value of the plant thus tied up was estimated at $6,500,000.

Although the improvement of this river has been discussed, surveyed and frequently reported upon, the first dam, that at Davis Island, was not opened until 1885 and since then another, at Beaver, has been completed, twenty-eight miles below. Four above and five below Beaver are under contract, but it is estimated that between Pittsburgh and Cincinnati thirty-seven locks and dams will be required and fourteen more below Cincinnati; all for a six-foot navigation, but already it is found insufficient and nine feet are now required. At this rate it may well be asked when will the 1,000 miles be available? This is all down grade and amongst the cheapest systems in the world — on a six-foot draught the estimated cost is .675 mills per ton-mile and on a nine-foot, .39 mill. The lowest rail movement is believed to be that across the Lake Divide, on the Bessemer and L. E. R. R. where the charge was 1.87 mills in 1901, and 2.10 mills in 1904 — or three times the river rate.

THE COASTWISE CANALS AND PRIVATE ENTERPRISE.

Again for more than twenty years urgent demands have been made for the creation of harbors of refuge along the New Jersey coast, where there have been 368 wrecks in ten years, which is recognized as one of the most dangerous on the great bay between Cape Cod and Cape Hatteras, but while several estimates have been submitted for projects costing from three to four millions

each they have been rejected as unworthy of improvement because of the absence of sufficient local commerce, caused by the existing bars which it is desired to remove. The interior coastwise canals have been recommended for about a century, but as yet only a few links have been built and those mainly by private and State aid. Massachusetts, has authorized private companies to open a canal across Cape Cod; New Jersey, across its girdle; Delaware and Maryland through their peninsula; Virginia from the Chesapeake to Albemarle Sound; South Carolina from the Santee to the Cooper rivers twenty-two miles, opened in 1802; and many others. The State of Illinois has authorized the levying of a special tax which has been expended in cutting the Chicago Drainage Canal through the Sag to the Illinois river. Thus past history and present experience point conclusively to the greater efficiency of the policy of constructing local works under local legislation and and supervision rather than to attempt to legislate for the entire country, by general appropriations made in Congress where so many other matters of a political nature consume time and prevent action, or where sectional jealousies have operated to restrain important measures. Even at this date there are said to be works recommended for approval aggregating nearly $500,000,000, in rivers and harbors alone, to meet immediate demands, yet it is extremely difficult to pass a bill for even the most urgent improvements. So that it has recently been deemed necessary to authorize private parties, corporations or municipalities to make their own improvements at their own cost subject to the approval of the plans by the Government, but without authority to charge tolls, or to collect revenues. As this is not a practical, commercial proposition, it has been further amended, in the last act, by giving authority in several special instances to private individuals to open channels and charge tolls, the Government reserving the right to recover control after a period of years.

Thus the pressure for commercial channels which it is beyond the power of the general Government to furnish in a reasonable time, is leading back to the original policy of local control and development of the lines of least resistance for our internal commerce which has done so much to open up the country prior to the destruction of our merchant marine in 1867 when it was the pride of the nation, and mistress of the seas.

If the Government desires to adhere to the policy of expending seventy-five per cent. of its revenues for the war, navy and pension establishments it would seem to be wise to surrender its jurisdiction over the secondary rivers and harbors, to local or State authorities that there may be opportunities afforded for the creation of channels of ample capacity not only for commerce but also for the use of the military and naval arms of the service in case of necessity that they may be operated on safe strategic bases between naval depots. Thus may the waters of the country be emancipated from the shackles which have so seriously retarded their development.

THE OLIGODYNAMIC ACTION OF COPPER FOIL ON CERTAIN INTESTINAL ORGANISMS.

BY HENRY KRAEMER.

(Read April 13, 1905.)

Carl von Nägeli, probably the greatest botanist of the last century, being both a philosopher and a true scientist, passed away on May 10, 1891. Among his papers was found the manuscript of a paper entitled "Ueber oligodynamische Erscheinungen in lebenden Zellen," which, together with an added note by Cramer, was published by Schwendener several years after his death in Neue Denkschriften der schweizerischen naturforschenden Gesellschaft.[1]

This really remarkable paper, while it has attracted considerable attention, does not seem to have been given the credit in some quarters that its merits deserve. In the light of more recent biological studies it has proved to be one of the most important papers that was written by Nägeli, and illustrates both the fertility of his resources and the incisiveness of his genius.

In this paper Nägeli showed how exceedingly sensitive certain living plants are to very minute quantities of various metals. For forty years he had been studying the algæ, but it was not until some time in the '80's during an illness that he observed that if algæ were placed in distilled water they were killed. This he at first attributed to various causes, but found upon analysis of the water that it contained traces of copper, and later experiments showed that the copper, which had been dissolved by the water in its passage through the copper still, was the toxic agent. He then carried on a large number of experiments placing copper coins in distilled water, and even went so far as to calculate approximately the amount of copper which was dissolved.

[1] For example, in the English translation of Pfeffer's Physiology of Plants, Vol. II, page 260, it is stated that copper is poisonous to *Spirogyra* in the proportion of one part of copper to 1,000 million parts of water, an observation made by Nägeli in the paper referred to above, and yet no mention of this paper is made in the citation of literature, which would lead the reader to believe that one of the other investigators quoted deserved the credit for the discovery.

In these experiments Nägeli used 2-pfennig pieces, consisting of 95 parts of copper, 4 of tin and 1 of zinc. These were cleaned with sand, and twelve of them were placed in 12 liters of distilled water and allowed to remain for several days. The solution was evaporated, the residue dissolved in hydrochloric acid, and the copper precipitated as sulphide. This precipitate was dissolved in nitric acid and an excess of ammonia added, producing a blue solution. On comparing the intensity of color of this solution with that of other solutions containing known quantities of copper sulphate, Nägeli estimated that it contained 1.3 parts of copper to 100 million parts of water. He found that this solution was toxic to various species of *Spirogyra*, and a further experiment showed that if the solution were diluted ten times, that is, so that it contained 1.3 part of copper to 1,000 million parts of water, it would still kill *Spirogyra*.

Inasmuch as solutions containing such extremely minute quantities of copper were toxic to *Spirogyra*, Nägeli was inclined to believe that the toxic action was different from ordinary chemical poisoning. This view appeared to him to be strengthened by the fact that the effects produced in the cells were different from those produced by ordinary poisons or those resulting from the natural death of the organism.

It has been supposed by some later investigators[1] that Nägeli did not regard the copper as being in a state of solution, yet the experiments just described clearly show what his information was on this point, and in another part of his paper he distinctly states that he so regards it. The marvellous thing to him, as to us, was that such minute quantities of copper exerted toxic action, and at first he was inclined to believe that the effect produced was due to a new force "Isagität," and in his original manuscript he used the word "isagische" in describing it. But this term was later replaced

[1] On page 23 of his paper Nägeli says, "Die oligodynamischen Eigenschaften des Wassers lassen sich also in allen Fällen auf Stoffe, die im demselben gelöst sind, zuruckführen. Nun weicht aber das durch Metalle oligodynamische gewordene Wasser in seinem Verhalten wesentlich ab von anderen Lösungen. Eine Salz or Zuckerlösung verliert ihre eigenschaften nicht, wenn unlösliche Körper in dieselbe gelegt werden und sie erteilt den Wandungen des Gefässes nicht die Fähigkeit, reines Wasser wieder salsig or süss zu machen, währende analoge Erscheinungen bei den Kupferlösungen eintreten."

by that of "oligodynamische" derived apparently from two Greek words meaning the force within a small quantity of substance.[1]

There seems to be some confusion among recent writers as to the condition of the copper produced by placing copper foil in water, and it is customary to speak of the solution as being a solution of colloidal copper. While it has been customary since the classical experiments of Graham to apply the name colloid to those substances which in solution or suspension will not pass through animal membranes, still recent researches have shown as pointed out by Noyes[3] that there are two subclasses of colloidal mixtures, — the one having the characteristic properties of true solutions, that is, possessing osmotic pressure, diffusibility and usually a limited solubility at some temperature; the other being without these properties and being in the nature of macroscopic and microscopic suspensions. Considering the origin of the copper in solution it would properly belong to the class of colloidal suspensions, but it has none of the properties of this class of substances; and it differs fundamentally from the so-called colloidal solutions not only in origin but in that it possesses the property of permeating colloids, as the cell wall and the organized contents of the cell, thereby producing marked disturbances in the cell and thus resembling the crystalloids.

It is well known as stated by Copeland and Kahlenberg[2] (page 455) that "every metal in contact with water and air is subject to some change. It reacts with oxygen and carbonic acid dissolved in water, or with the water itself, to form oxides, hydroxides, carbonates, basic carbonates, or acids, which in greater or less degree pass into solution. When this chemical action is sufficient for the effect to become visible, the metal is tarnished or corroded; and even gold and platinum lose their lustre." Nägeli in his paper (page 24) says that a solution of copper manifesting oligodynamic properties results only when copper is placed in water containing oxygen and carbon dioxide; but so far no one has determined which compound, or compounds, of copper is formed under these conditions.

[1] As further indicating the meaning that Nägeli had in mind we quote from his paper (page 8) as follows: "Ich will nun, um eine bestimmte und feste Bezeichnung zu haben, die specifische Wirkungen des Giftes die chemischen, die jenigen der noch unbekannten Ursache, in dem ich dem Endresultat vorgreife, die *oligodynamischen* nennen."

While Nägeli's paper was incomplete he nevertheless had carried on a sufficient number of experiments to show that there is a marked difference in the sensitiveness of various species of *Spirogyra* to the oligodynamic action of copper. He found, for instance, that *Spirogyra orthospera* and other *Spirogyras* with lense-shaped nuclei were more resistant than the remaining species.[1] He also showed that there was a marked difference in the sensitiveness in some of these plants (*S. nitida*) at different times of the day.

While Nägeli confined his attention to studies on *Spirogyra* using copper coins[2] to produce the oligodynamic effects, other investigators since his time have carried on experiments with other organisms both plant and animal and have employed metallic copper and salts of copper as well. One of the most important of these researches is that by Israel and Klingmann.[4] These investigators studied the effects of copper on certain bacteria (as *Bacillus typhi, B. coli and Microspira comma*), as well as certain animal organisms (as *Amoeba, Difflugia oblonga, Hematococcus pluvialis, Paramecium Bursaria, Spirostomum ambiguum, Vorticella microstoma* and *Stylonychia mytilus*), and also on *Spirogyra*. They used copper foil and found that it had a marked toxic effect on all of the bacteria that they worked with, *B. typhi* being the most sensitive. They also found that by placing the solutions of copper containing the organisms in an incubator at a temperature of 35°–40° C. the toxic effects were manifested in 1 hour, whereas at the ordinary temperature similar effects were produced in two hours. In the case of the animal organisms, while the toxic effects were visible in most instances in but a few minutes, in *Vorticella* it required several hours for any toxic effects to be observed and it was found that *Stylonychia* might resist the action for 24 hours. These authors further found that water in which copper foil had been placed for 24 hours, could be diluted 100 times and still manifest oligodynamic effects on *Spirogyra*. In the latter instance

[1] Cramer made a similar observation with *S. setiformis* (?).

Israel and Klingmann (page 307) found that *S. Crassa* was killed in 15 minutes, *S. majuscula* in 30 minutes and *S. laxa* in 75 minutes.

[2] During his investigation Nägeli also discovered that minute quantities of other metals, as silver, lead, tin, iron and mercury manifested oligodynamic properties similar to copper.

the time required was 24 hours as against 8 minutes in the first instance.

While we have seen that solutions containing minute quantities of copper are exceedingly toxic to certain organisms, other investigators have shown that various plants not only withstand the influence of relatively large quantities of copper sulphate, but under certain conditions even appear to be benefited by its presence. With these various data before us we may say that while copper has a specific toxic action even in very minute quantities on certain organisms, it should be borne in mind that these same organisms manifest a specific sensitiveness towards copper and various other metals.[1]

These data are not only of great interest from a scientific point of view but in their practical application are of very great importance, and it was to be expected that pharmacologists would appreciate the important bearing of this line of investigation on their work. Cushny[5] among pharmacologists early recognized the value of these researches and the possibilities in their application in the prevention and treatment of disease. He states that while copper is comparatively harmless to man, yet it is exceedingly toxic to certain microörganisms and intestinal parasites. He says:

"Small quantities of copper may be taken for indefinite periods without any symptoms being induced, so that so far as man is concerned the general action of copper is unknown. . . . On the other hand, copper is a deadly poison to several of the lower plants. Thus, traces of copper added to the water in which they live, destroy some of the simpler algæ, and Nägeli asserts that 1 part

[1] While various explanations might be offered to show why such extremely minute quantities of copper in solution are sufficient to kill unicellular and filamentous algæ, bacteria, and unicellular animal organisms, and yet not affect multicellular plants and animals, whose cells are as delicate in structure as those of the unicellular organisms, it seems that this is in a measure due to the fact that in the latter the entire individual is comprised in a single cell, which performs all the vegetative as well as reproductive functions, and being entirely surrounded by the copper solution, all the life process are affected, there being no way for the organism to distribute the solution to other cells, and thus by a dilution minimize the toxic action of the copper. Or if some of the cells in the multicellular organism are destroyed or injured by exposure to the solution, others are formed to take their place from the more or less deep-seated meristematic cells. It is true that the idiosyncrasies in these organisms should also be borne in mind, some of them being more resistant than others.

of copper in 1,000,000,000 parts of water is sufficient to kill these plants. . . . Locke found that the traces of copper contained in water distilled in copper vessels were sufficient to destroy tubifex (one of the annelid worms) and tadpoles, while Bucholtz states that the development of bacteria is stopped by a solution of copper sulphate under 1 per cent. in strength. Copper thus seems to have a very powerful poisonous action on certain living forms and to be harmless to others, and the subject deserves further investigation. It is possible that it may prove to act prejudicially to some human parasites, and it is certainly less dangerous to man than many other remedies used as parasiticides and disinfectants."

It was not, however, until the publication of the bulletin on "A Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies" by Moore and Kellerman,[6] nearly a year ago, that the very great practical significance of work along these lines became apparent and general interest was aroused in the subject.

Since last fall we have been carrying on a series of experiments in the Microscopical Laboratory of the Philadelphia College of Pharmacy[1] with the view of testing the efficiency of metallic copper for destroying typhoid and colon bacilli in water. Some of the results obtained have already been published.[7]

In presenting the results of our experiments sufficient of the details will be given to show the manner in which the work was conducted.

In the first series of experiments here recorded water under three different conditions was employed: (*a*) Distilled water which was prepared from tap water by first treating it with potassium permanganate and then distilling it two or three times by means of apparatus constructed entirely of glass; (*b*) filtered tap water, prepared by means of a Berkefeld filter attached to a copper spigot; (*c*) tap water, collected after being allowed to run for five minutes, the spigot being the usual copper one. All of these were sterilized in an autoclave at 110° for 30 minutes.[2]

The cultures of typhoid and colon which were used were pure cultures developed in bouillon for 18 to 24 hours.

[1] I acknowledge my indebtedness to Mr. John R. Rippetoe for valuable assistance in carrying on the experiments recorded in this paper.

[2] In all of our work we found in the blank experiments that water which had been sterilized in an autoclave remained sterile.

To 200 c.c. of samples of water prepared as stated, and contained in sterile Erlenmeyer flasks, were added two 3-mm. loops of the fresh bouillon cultures of typhoid and colon bacilli respectively. Counting the duplicate experiments provided for, we thus had a series of 12 flasks, 6 of them containing typhoid bacilli, and 6 colon bacilli.

For determining the number of organisms, 1 c.c. of the respective solutions was transferred directly to a Petri dish by means of a sterile 1-c.c. pipet, and to this was added 10 c.c. of Heyden's nutrient agar, which had been kept at a temperature of 40° C. for some time. Three separate plates of the water in each of the 12 flasks was made immediately upon the addition of the cultures, and both the plates and the flasks were kept at a temperature of 35°

TABLE I.—EXPERIMENTS WITH *Bacillus coli.*

Plates Made.	Water Without Copper Foil.			Water With Copper Foil.		
	Triple Distilled Water	Filtered Tap Water.	Tap Water.	Triple Distilled Water.	Filtered Water.	Tap Water.
At time of adding culture.	7,746	11,246	8,283	8,866	4,410	6,790
At end of 4 hours.	7,655	5,075	7,665	No organisms.	No organisms.	No organisms.
At end of 8 hours.	7,735	3,115	7,000	"	"	"
At end of 24 hours.	1,000,000	1,000,000	1,500,000	"	"	"
At end of 48 hours.	1,200,000	1,600,000	2,000,000	"	"	"
At end of 6 days.	1,200,000	1,000,000	1,200,000	"	"	"
At end of 14 days.	1,060,000	910,000	2,245,000	....	....	....
At end of 21 days.	700,000	462,000	650,000	....	....	....
At end of 28 days.	700,600	462,446	649,666	....	....	....
At end of 53 days.	602,000	456,000	693,000	....	....	....
At end of 60 days.	583,200	421,000	687,333	....	....	....
At end of 83 days.	215,600	128,766	206,950	....	....	....
At end of 90 days.	208,133	48,433	147,000	....	....	....
At end of 130[1] days.	289,333	146,543	225,400	....	....	....

[1] The nutrient medium used in the plates made at the end of 130 days was agar having an acidity of 0.5 percent.

C. to 37° C. To six of the flasks were then added strips of copper foil about 15 mm. wide and 18 cm. long, these being corrugated in such a manner that the entire surface was exposed to the water.

Plates were made from all the 12 flasks at the end of 4 hours and 8 hours, and 1 day, 2 days, and 6 days, even in the cases where no organisms remained, and in the cases in which they continued to develop, also at the end of 14, 21, 28, 53, 60, 83, 90, 120, 130 and 134 days. The results are given in the accompanying tables.

TABLE II.—EXPERIMENTS WITH *Bacillus typhosus*.[1]

Plates Made.	Water Without Copper Foil.			Water With Copper Coil.		
	Triple Distilled Water.	Filtered Tap Water.	Tap Water.	Triple Distilled Water.	Filtered Water.	Tap Water.
At time of adding culture.	3,740	4,750	3,675	3,986	127	1,400
At end of 4 hours.	2,835	No organisms.	3,815	No organisms.	No organisms.	No organisms.
" " 8 "	3,850	"	1,995	"	"	"
" " 24 "	3,750	"	1,435	"	"	"
" " 48 "	3,815	"	1,540	"	"	"
" " 6 days.	1,850	"	....	"	"	"
" " 14 "	16,380	"	3,920	....	....	....
" " 21 "	39,690	"	65,500	....	....	....
" " 28 "	153,600	"	221,867	....	....	....
" " 60[2] days.	295,866	"	961,800	....	....	....
" " 90 "	239,400	"	346,500	....	....	....
" " 120 "	78,750	"	9,156	....	....	....
" " 134 "	34,440	"	7,875	....	....	....

[1] Bouillon cultures of the different samples of water, at the end of 60 days, gave with Widal's test the characteristic behavior of typhoid organisms. After 60 days the organisms were found to be very long and more or less filamentous and did not respond to Widal's test. I am indebted to Dr. Herman B. Allyn, Philadelphia, for specimens of typhoid blood.

It is seen in the foregoing tables that in all the flasks to which copper foil had been added all of the organisms were destroyed in less than four hours, and furthermore the solutions remained sterile as shown by plates made for a number days thereafter.

I may say that every single experiment which we have conducted, not only those given in the foregoing tables, but all others, shows that copper foil is exceedingly toxic to colon and typhoid bacilli, particularly the latter.

It will be seen further that in the filtered water, to which no copper foil had been added, the typhoid organisms did not develop as was the case with the tap water and distilled water, although

there was a larger number of organisms to begin with; while the colon bacilli multiplied considerably in the filtered water still there was a very marked inhibiting action. At first I was inclined to attribute this diminution in the number of the organisms to minute traces of copper in the flasks, but subsequent experiments showed that this was not the case. I was, then, inclined to attribute these rather anomalous results to the presence of extremely small quantities of copper dissolved by the water in its necessarily slow passage through the copper spigot to which the filter was attached.

In order to test further the validity of this assumption another series of experiments was conducted using (*a*) tap water, (*b*) water filtered through a stone filter,[1] and (*c*) water filtered through a Berkefeld filter. The water in each case was sterilized in an autoclave at a temperature of 110° C. for 30 minutes, and 18- to 24-hour cultures of typhoid and colon bacilli were respectively added to the samples of water at the ordinary temperature. The results are summarized as follows:

TABLE III.—EXPERIMENTS WITH *Bacillus coli* AND *B. typhi* IN FILTERED WATER.

Plates Made.	*Bacillus coli.*			*Bacillus typhi.*		
	Tap Water.	Stone Filtered Water.	Berkefeld Filtered Water.	Tap Water.	Stone Filtered Water.	Berkefeld Filtered Water.
At time of adding culture.	5,040	10,611	10,269	7,875	1,512	1,764
At end of 2 hours.	6,426	18,270	6,600	5,040	....	....
" " 4 "	8,505	24,570	5,500	2,714	2,520	No organisms.
" " 6 "	6,930	28,350	2,646	250	....	"
" " 8 "	16,065	77,175	3,654	150	2,930	"
" " 24 "	315,000	630,000	150,000	38	3,829	"
" " 48 "	630,000	1,000,000	200,000	39	1,820	"
" " 7 days.	....	....	....	....	9,000	"
" " 14 "	1,289,333	1,505,700	599,333	80,770	43	"
" " 21 "	....	....	....	....	No organisms.	"
" " 30 "	900,000	1,260,000	94,500	No organisms.	"	"
" " 60 "	730,800	945,000	149,331	"	"	"

[1] In the preliminary experiments with samples of water that had been filtered through a stone filter or a Jewett filter, it was found that there was a similar inhibiting action on the organisms to that of water from the Berkefeld filter. This action was supposed to be due to the influence of the copper in the spigot attached to the receiver of the filter, and was overcome by removing the spigot and using a rubber stopper fitted with a glass tube.

It is seen from the foregoing table that while we began with approximately 5,000 organisms of colon bacilli to the cubic centimeter in the case of the tap water, there were over 700,000 at the end of sixty days; and that in the case of the stone filtered water where the initial number of organisms was about 10,000 they increased on an average similar to those in the tap water. In the case of the water from the Berkefeld filter, however, beginning with 10,000 organisms to the cubic centimeter, there was a rapid diminution of the organisms, so that but about 2,500, or about 25 per cent. of the organisms persisted at the end of six hours, and while they continued to multiply after this still the number was considerably less than in either the tap water or stone filtered water, showing that with Berkefeld filtered water there is some agency which inhibits the growth of the colon bacilli. This we concluded to be due to the copper dissolved from the spigot to which the filter was attached, as already suggested.

In the experiments with the typhoid organisms it was found that they multiplied in number in both the tap water and stone filtered water persisting for fourteen days, after which they disappeared, as was also the case in some other experiments; but in the case of Berkefeld filtered water they entirely disappeared within four hours, which was also the case in three other experiments not here recorded. It may also be stated that it was not unusual to observe in the case of both tap and stone-filtered water, where cultures of the typhoid bacillus were used, that if the organisms persisted until the fourteenth day, they would multiply enormously after that as shown for tap water and distilled water in Table II.

In an investigation of this kind many lines of experiment are suggested, and it was thought desirable to carry on another series of experiments with a view of testing the toxicity of solutions in which metallic copper had been allowed to remain for varying lengths of time. In these experiments sterilized distilled water and stone filtered water were used. To 600 cc. of water in a graduate 8 strips of copper foil 15 × 130 mm. were added. The graduate was agitated continuously and 100 cc. of the solution were removed at the end of 1, 5, 10, 20 and 30 minutes. The respective solutions were placed in Erlenmeyer flasks and sterilized in an autoclave at 110° C. for 30 minutes. To these were added 18- to 24-hour cultures of typhoid bacilli, and plates made with results as indicated in the two following tables:

TABLE IV.—EXPERIMENTS WITH *Bacillus typhi* IN DISTILLED WATER IN CONTACT WITH COPPER FOIL FOR VARYING LENGTHS OF TIME.

Plates Made.	Water *without* Copper.	Water in Contact *with* Copper for				
		1 minute.	5 minutes.	10 minutes.	20 minutes	30 minutes.
At time of adding culture	3,451	7,119	7,420	6,791	8,631	12,726
At end of 2 hours.	5,292	No organisms.	No organisms.	2,139	3,150	6,188
" 4 "	6,489	"	"	No organisms.	25	420
" 6 "	5,950	"	"	"	3	35
" 8 "	4,410	"	"	"	No organisms.	12
" 24 "	6,489	"	"	"	"	No organisms.
" 48 "	8,410	"	"	"	"	"
" 3 days.	11,466	"	"	"	"	"
" 4 "	7,560	"	"	"	"	"
" 7 "	2,898	"	"	"	"	"

TABLE V.—EXPERIMENTS WITH *Bacillus typhi* IN STONE FILTERED WATER IN CONTACT WITH COPPER FOIL FOR VARYING LENGTHS OF TIME.

Plates Made.	Water *without* Copper.	Water in Contact *with* Copper for				
		1 minute.	5 minutes.	10 minutes.	20 minutes.	30 minutes.
At time of adding culture.	5,050	4,725	7,221	6,111	13,482	11,403
At end of 2 hours.	4,599	4,977	6,615	7,056	16,000	11,088
" 4 "	6,300	5,859	3,906	6,339	14,000	15,482
" 6 "	7,119	6,300	4,250	5,418	8,946	5,574
" 8 "	4,914	8,064	5.481	5,645	7,951	5,624
" 24 "	10,710	3,213	2,205	1,925	4,410	....
" 48 "	10,700	1,155	142	104	790	3
" 3 days.	11,277	152	No or ganisms.	No organisms.	123	No organisms.
" 4 "	10,395	No organisms.	"	"	No organisms.	"
" 7 "	7,899	"	"	"	"	"

Table IV shows that in the experiments made with distilled water, the mere contact of the copper foil with the water for from 1 to 5 minutes imparted to it sufficient toxicity, or oligodynamic property, to kill the typhoid organisms placed in the solution within two hours, when the organisms did not exceed approximately 7,000 to the cubic centimeter, or 700,000 to the entire solution. Where the number of organisms in the solution exceeded this number approximately three-tenths of 1 per cent. persisted four to eight hours longer.

In the case of stone filtered water (Table V) a longer time was required to affect the organisms. This is probably accounted for by the fact that the water contained other substances which modified the action of the copper either precipitating it, absorbing it, or even adsorbing it, and thus weakening the solution.[1]

As showing the influence of a material which would be in the nature of a food to the organisms and which at the same time would have a tendency to inhibit the oligodynamic actiòn of the copper solution, the following experiments were conducted using filtered water: (*a*) Berkefeld filtered water; (*b*) stone filtered water. In both series of experiments 1 cc. of nutrient bouillon was added to 200 cc. of water, which was then sterilized in the autoclave, and the typhoid organisms added after cooling.

TABLE VI.—EXPERIMENTS WITH *Bacillus typhi* IN FILTERED WATER CONTAINING BOUILLON.

Plates Made.	Berkefeld Filtered Water.		Stone Filtered Water.	
	Without Bouillon.	*With* Bouillon.	*Without* Bouillon.	*With* Bouillon.
At time of adding culture.	7,245	1,296	14,044	2,151
At end of 4 hours.	550	9	11,907	1,323
" 8 "	No organisms.	5	7,560	4,820
" 24 "	"	17	No organisms.	3,000,000
" 48 "	"	2,500,000	"	4,500,000
" 7 days.	"	7,000,000	....	2,255,000
" 14 "	"	....	11,109	....
" 30 "	"	....	6,466	....
" 60 "				

In the case of the Berkefeld-filtered water it is seen that there was no growth in the flasks to which bouillon had not been added, after four hours; and while there was a diminution of the number

[1] Nägeli found (p. 13 of his paper) that the oligodynamic action of a copper solution could be lessened by the introduction of the following substances: Sulphur (either roll or flowers), carbon (either graphite or soot), coke, coal, peat, black oxide of manganese, starch, cellulose (either as Swedish filter paper, or cotton, linen or wood fiber), silk, wool, stearic acid, paraffin, gum, dextrin, egg albumin and glue.

True and Oglevee[8] have studied the influence of insoluble substances on the toxic action of poisons and have confirmed several of Nägeli's observations.

Moore and Kellerman have shown in their recent bulletin the relative decrease of toxicity of copper sulphate solutions depending on the amount of organic matter present, the amount of carbon dioxide in solution or the temporary hardness of the water.

of organisms in those solutions containing bouillon between the first 4 and 24 hours, there was after this a marked increase in growth. This increase in development would appear to begin after the last inhibiting traces of copper are removed, either by precipitation in the organisms or by the bouillon.

Other experiments which we conducted showed that there was a difference in the persistence of the typhoid organisms depending upon whether the cultures added to the water were 24-hour or 14-day bouillon cultures, as seen in the following table.

TABLE VII.—EXPERIMENTS WITH CULTURES OF *Bacillus typhi* OF DIFFERENT AGES.

Plates Made.	Tap Water.		Berkefeld Filtered Water.	
	24-Hour Cultures.	14-Day Cultures.	24-Hour Cultures.	14-Day Cultures.
At time of adding cultures.	3,058	1,050	1,983	952
At end of 4 hours.	682	1,105	40	574
" 8 "	440	604	No organisms.	215
" 24 "	137	217	"	106
" 48 "	63	179	"	150
" 7 days.	No organisms.	49	"	35

The figures in Table VII, show that the older cultures of the typhoid organisms were most resistant in the tap water, and that they survive over 7 days in Berkefeld-filtered water, the 24-hour cultures usually being destroyed in about 4 hours.

TABLE VIII.—EXPERIMENTS ON TAP WATER WITH COPPER FOIL AND COPPER SULPHATE.

Plates Made.	Tap Water *without* Copper Foil or Copper Sulphate.		Berkefeld Filtered Water.	Tap Water with Copper Foil.	Tap Water with Copper Sulphate.	
					1 Part to 100,000	1 Part to 1,000,000
At time of adding copper foil or copper sulphate.				39,000	8,233	8,233
On drawing tap water or before filtering.	39,000	8,233	46,800			
After filtering.			666			
At end of 2 hours.	32,666	9,500	....	35,666	300	1,833
" " 4 "	21,300	7,766	....	29,266	66	1,300
" " 6 "	40,900	10,200	....	20,516	200	2,233
" " 8 "	41,000	13,333	....	9,866	300	1,166
" " 3 days.	68,933	102,200	61,466	609,900	3,633	112,300
" " 6 "	....	87,100	500,200	....	185,000	97,150
" " 10 "	27,133	111,000	395,300	33,600	211,760	134,000
" " 13 "	....	....	343,700	....	....	....

At the beginning of our investigation a number of experiments were made with a view of testing the comparative efficiency of both copper foil and copper sulphate in destroying the organisms in tap water, and it is thought that the results obtained are of sufficient interest to present at this time.

It is observed that in the case of the Berkefeld filtered water, 99 per cent. of the original number of organisms were removed by the process of filtration. When copper foil was introduced into the water about 75 per cent. of the organisms were destroyed in 8 hours, although in other experiments where larger quantities of water were used from 85 to 97 per cent. of the organisms were destroyed. When copper sulphate was added to the tap water, so that there was 1 part to 100,000 of water, 97 per cent. of the organisms was destroyed in 8 hours. When the strength was reduced so that there was 1 part of copper sulphate to 1,000,000 parts of water, there was a reduction of 86 per cent.

Owing to the sensitiveness of typhoid and colon bacilli to the influence of copper, as previously shown, it may be inferred that they would have been included in the 75 to 97 per cent. of the organisms destroyed.

CONCLUSIONS.

From the experiments thus far conducted as well as the results obtained by other writers, the following conclusions may be drawn:

1. Certain intestinal bacteria like colon and typhoid are completely destroyed by placing clean copper foil in water containing them, or by adding the organisms to water previously in contact with copper foil.

2. The toxicity of water in which either copper coins or copper foil has been added is probably due to a solution of some salt of copper, as first suggested by Năgeli.

3. The copper is probably in the form of a crystalloid rather than that of a colloid, as it has the property of permeating the cell walls and organized cell contents of both animals and plants, thereby producing the toxic effects.

4. While the effects produced by the oligodynamic action of copper are apparently different from those of true chemical poisons, the difference is probably in degree only and not in kind.

5. Certain lower organisms including both plants and animals possess a specific sensitiveness to minute quantities of copper, and

it has been shown that they are not restored on transferring them to water free from oligodynamic properties.

6. Oligodynamic solutions of copper are obtained by adding either copper coins, copper foil or salts of copper to water; when copper foil is used, sufficient copper is dissolved by the distilled water in 1 to 5 minutes to kill the typhoid organisms within two hours.

7. A solution of copper may lose its toxicity by the precipitation of the copper as an insoluble salt or compound; by its absorption by organic substances; or by adsorption by insoluble substances.

8. The oligodynamic action of the copper is dependent upon temperature as first pointed out by Israel and Klingmann.

9. The effects of oligodynamic copper in the purification of drinking water are in a quantitative sense much like those of filtration, only the organisms removed, like *B. typhi* and *B. coli* are completely destroyed.

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THE EFFECT OF PRESERVATIVES ON METABOLISM.

BY H. W. WILEY, M.D.

(*Read April 13, 1905.*)

The question of the use of preservatives in food products has of late assumed an importance greater even than in previous years. A tendency to legislation of a prohibitory character has developed in all civilized countries. Many preservatives are now forbidden by law in Germany, France, Italy, Spain, Austria, and many of the States of the United States. It seems that it is scarcely just to legislate against preservatives individually rather than as a class. Universally excepted from prohibitory or restricted legislation are the preservatives in common use, namely, sugar, salt, vinegar and wood smoke. The basis of all prohibitory legislation, at least, the alleged basis lies in the fact that the preservatives restricted or forbidden are injurious to health. If literature on the subject is consulted some conflicting statements are found emanating from scientific sources apparently of equal reliability. It is evident, therefore, that there is a very widespread difference of opinion among physiological chemists and hygienists respecting the effect of preservatives added to foods upon the public health. The data of research are very extensive in experiments in vitro, with the lower animals and with man. It cannot be denied that there are many grounds for the prohibitive and restrictive legislation referred to. There are other questions which must be considered in connection with this, namely, the dangers which attend the use of nonpreserved foods and the effects which the prohibition of preservatives might have upon the price of foods. The latter is a purely economic subject and does not enter into the present discussion. It is evident that if a preservative is injurious to health it will in some way affect the metabolic process. It will either derange digestion or interfere with assimilation and excretion.

There are many apparently almost insurmountable difficulties in the experimental determination of this problem with man himself. A merely negative result is not sufficient to secure a verdict of acquittal. The reason of this is apparent, namely, the fact that in-

dividuals present such marked differences in their powers of resistance. One person may be affected with great facility while another person, subjected to the same treatment shows no sign of injury. The object of restrictive laws is, of course, the protection of the weakest and not of the strongest. Hence, I think it may be laid down as a direct principle of legislation that the addition of any substances to foods whatever not necessary in their preparation which affect the health of the most susceptible should be prohibited or so regulated that danger of injury even of the weakest may be eliminated.

I have now to briefly record the results of experimental work on strong and healthy young men. I can do no more than merely state the principal points which were noticed. First, the action of borax and boric acid on nitrogen metabolism was extremely slight. There was, however, a very slight tendency manifested in the experiments which extended over a period of nearly eight months to inhibit the excretion of nitrogen. The general effect, however, on nitrogen metabolism is not of sufficient magnitude to warrant the drawing of any definite conclusions. The effect of the borax and boric acid upon the metabolism of phosphoric acid is very marked. A very much larger quantity of phosphoric acid is excreted under the influence of these preservatives than without them. Borax and boric acid appear to increase the digestibility of the fats in food. In other words there is slightly less fat in the feces during the administration of these bodies than without them. These preservatives have a slight tendency to diminish the utilization of calories of foods. In other words, there is a great number of non-metabolized calories in the feces during the administration of the preservatives than without them. Both boric acid and borax have a slight tendency to increase the traces of free albumen in the urine. Boric acid has a decided tendency to increase the acidity of the urine. Borax has a decided tendency to diminish the acidity of the urine, establishing often the amphoteric reaction and occasionally an alkaline reaction. Both these bodies when exhibited over long periods in small quantities tend to disturb the digestion by diminishing the appetite and inducing a feeling of heaviness in the head or often headache of a persistent character. The results of these influences are seen in a gradual diminution of weight.

In large doses, from one to three grams per day, both boric acid

and borax, when their use is continued for a short time, tend to produce a feeling of distress and even nausea. There is, however, no tendency to produce diarrhea. The general effect produced by borax and boric acid upon health and digestion is decidedly unfavorable, whether by large doses over a short period of time or in the case of small doses, namely seven and one half grains or half a gram per day, over a period of fifty days.

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NOTES ON THE OSTEOLOGY OF SINOPA, A PRIMITIVE MEMBER OF THE HYÆNODONTIDÆ.

BY W. D. MATTHEW.

(*Read April 13, 1905.*)

The following observations are based upon a nearly complete skeleton of a Middle Eocène creodont discovered by Mr. Walter Granger near Fort Bridger, Wyo., in 1902. The specimen is the property of the National Museum and the full description will be published under the auspices of that institution. I am indebted to the Secretary of the Smithsonian Institution for permission to publish this abstract in advance.

The skeleton is unusually well preserved, and practically complete except for the feet. Most of one fore and one hind foot are preserved, the others are missing. It is believed to be one of the most perfect skeletons ever found in this formation and is of interest as a typical generalized Creodont. The points of especial interest in its study were: (1) the relations of the Creodonta to marsupials and Insectivora, and (2) the relations of *Sinopa* to *Hyænodon* and to the Oxyænidæ.

Sinopa was the first fossil carnivore described from the Eocene of North America and is a characteristic genus of the Lower and Middle Eocene found in Europe as well as in this country. The dentition of this or allied genera has been well known from the descriptions of Cope and Scott, and Wortman in 1902 described a skull and some parts of the skeleton which he referred to *Sinopa*. The complete knowledge of the skeleton enables us to determine its relationships with certainty, and for the most part confirms the views hitherto generally accepted.

The animal was a little smaller than a coyote, but in proportions much more like the Tasmanian wolf, the lower limbs and feet being much shorter and less compact than in any of the Canidæ, and the tail long and heavy. The skull is long both in cranial and facial regions, the long basicranial region being very characteristic of carnivora, while in marsupials and insectivores the basicranial region is short. The mastoid has a small exposure on the side of the

skull, as in carnivora, while in marsupials and insectivores it has a large exposure on the back of the skull. The brain is very small and of inferior type, as in marsupials and all primitive mammals. The occipital and sagittal crests are high, as in the carnivorous marsupials. The tympanic bullæ are not preserved and probably were incompletely if at all ossified, and loosely attached to the skull as in marsupials and insectivores. In modern carnivora they are completely ossified and fast to the skull. But there is no trace in *Sinopa* of the supporting plates from the alisphenoid and basisphenoid bones around the margin of the bulla, the so-called "false bulla," which is more or less developed in most insectivora and marsupials. In *Hyænodon* the bullæ are ossified to a varying degree in the different species, in some apparently not at all, in others a loosely attached bony ring, in others again a complete osseous bulla; but there is no trace of false bulla.

The teeth resemble those of many carnivorous marsupials, the molars being triangular with transverse and oblique shearing edges; but the dental formula is that of eutherian mammals, three incisors, a canine, four premolars and three true molars, while the marsupials have four or five incisors, canine, three premolars and four true molars. The angle of the lower jaw is like that of typical carnivora, and shows no trace of the marsupial inflection. This inflected angle is seen quite as clearly in Cretaceous as in modern marsupials and is evidently a distinction of very ancient origin.

The details of construction of the skull, especially the basicranial bones and foramina, agree entirely with the true carnivora, and show that the marsupial resemblance is a superficial one.

The vertebræ agree with carnivora in all important points. The vertebral artery perforates the atlas and does not perforate the seventh cervical. This condition prevails in carnivora and most eutherians; in marsupials as far as I have examined, the reverse is the case.

There are 13 dorsals and 7 lumbars, making a dorsolumbar formula of *twenty* as in carnivora instead of *nineteen* as in marsupials. The dorsolumbar formula is known in only a few creodonts. In *Oxyæna*, and probably in *Patriofelis* and *Hyænodon*, it was twenty as in *Sinopa*; in *Dromocyon* nineteen according to Wortman. It is probable that in all Oxyænidæ and Hyænodontidæ it was twenty and in the Mesonychidæ nineteen, this family approaching the

marsupials in two or three other important characters, and differing rather widely from the remaining creodonta. The lumbar region is long and the vertebræ large with long transverse processes, indicating a flexible body with great leaping powers, as in primitive mammals generally. Among modern carnivora the cats, viverrines and mustelines retain more of this character than the other groups.

The limbs show a considerable degree of cursorial adaptation for an Eocene carnivore, the bones being longer and the feet more compact than in the majority of creodonts. The scapula is nearly as long and narrow as in the dogs (the anterior border is incomplete and is restored too wide in the mount); the humerus compares with that of the cat; the femur retains a vestigial third trochanter, but its distal end is deep and narrow, almost ungulate in type; the ulna is somewhat more robust than the radius, as in creodonts generally, and in most insectivora and marsupials; in modern carnivora the shaft of the ulna is reduced to a varying degree.

There are five well developed toes on each foot and the axis of symmetry in both fore and hind foot passes through the middle digit (mesaxonic) as in *Hyænodon*. In all modern carnivora and in the Mesonychidæ among creodonts, the axis of symmetry lies between the third and fourth digit (paraxonic). In the Oxyænidæ the weight is distributed over comparatively short spreading digits so that the axis of symmetry is not well defined (amphaxonic). The scaphoid, lunar and centrale bones of the wrist are separate as in creodonta, instead of united as in true carnivora; the arrangement of the carpals resembles that in *Hyænodon*, but their vertical diameters are greater. The fibula is large and has a considerable facet for the calcaneum, and the contact between astragalus and cuboid is slight as in *Hyænodon*.

The skeleton represents an undescribed species nearly allied to *S. rapax* Leidy. The skull described by Wortman as *Sinopa agilis* differs considerably in dentition, etc., and should be distinguished generically; the generic name *Prototomus* Cope, is probably available for this form. The most important distinctions from *Sinopa* in the teeth are the closely connate paracone and metacone on $M\frac{1-2}{}$, absence of metacone on $M\frac{3}{}$, reduced heels of the lower molars, and much compressed premolars.

In all respects *Sinopa* appears as a primitive member of the

Hyænodont phylum. The genera *Sinopa, Prototomus, Cynohyænodon, Pterodon* and *Hyænodon* show a series of stages in the development of a highly specialized sectorial dentition, and with some exceptions, in the specialization of the skull and skeleton so far as they are known. The geological occurrence of the known species of these genera precludes their being regarded as in the direct line of phyletic descent. *Sinopa* and *Prototomus* are found together in the Lower and Middle Eocene, while *Cynohyænodon, Pterodon* and *Hyænodon* occur together in the Oligocene. But without doubt the genera represent very closely the stages through which the phylum passed in its evolution, and that is about as much as it is safe to assert of most phylogenetic series.

The relationship of *Sinopa* to the Oxyænidæ, especially to *Limnocyon,* is not yet clear. There is a great deal of resemblance in skeletal characters, a marked diversity in the more significant features of the skull. Most of the resemblance, perhaps all, is to be explained as due to retention of primitive creodont characters, but some may indicate a nearer relationship of Hyænodonts to Oxyænids than to any other creodont family.

THE MARSUPIAL FAUNA OF THE SANTA CRUZ BEDS.

(PLATES I AND II.)

BY WM. J. SINCLAIR.

(*Read April 13, 1905.*)

The Patagonian marsupials of the Santa Cruz epoch are of peculiar interest from the relationship which they bear to certain Australian and Tasmanian forms. This relationship establishes the reality of a former land connection between the Australian region and South America, so plainly indicated by the distribution of the Tertiary marine mollusks, fishes, land shells, decapod crustacea and plants.[1]

These marsupials are referable to three families, remnants of which survive in widely separated parts of the world. The Thylacynidæ are represented by at least four genera in the Santa Cruz fauna, where they occupy the place of the placental carnivora. The Didelphyidæ include the genus *Microbiotherium* and several other imperfectly known forms, comparable in size to some of the smaller South American opossums. The Santa Cruz diprotodonts belong to a third family which may be called the Cænolestidæ. A single representative of this family, *Cænolestes*, survives in Ecuador and Colombia.

THE THYLACYNIDÆ.

This family is sharply separated from the Dasyuridæ and all other existing carnivorous marsupials by the absence of the metaconid in the lower molars and by the great reduction of the outer cingulum

[1] Ortmann, A. E., *Reports of the Princeton University Expeditions to Patagonia, 1896–1899*, Vol. IV, pp. 299–302, 1902.

Ortmann, A. E., "The Geographical Distribution of Freshwater Decapods and its Bearing upon Ancient Geography," *Proc. Amer. Phil. Soc.*, Vol. XLI, pp. 267–400, 1902.

Pilsbry, H. A., "Distribution of Helices in Time and Space," *Manual of Conchology*, Series 2, Vol. IX, pp. xxxviii *et seq.*, 1894.

Lydekker, R., "A Geographical History of Mammals."

Hedley, C., "Considerations on the surviving refugees in Austral lands of ancient Antarctic life," *Proc. Roy. Soc. N. S. Wales*, August, 1895, p. 3, footnote 1.

and styloid cusps in the upper teeth. In the Dasyuridæ, these styles are almost as high as the outer cusps of the trigon. The family name, based on the Tasmanian marsupial wolf *Thylacynus*, was proposed by Buonaparte in 1838, and may very properly be extended to include the related South American forms.

The Santa Cruz thylacynes were predatory carnivores. An indication of their pugnacious habits is afforded by the traces of wounds received in fighting, which are found occasionally on the skull and mandible.

These carnivores have been placed by Ameghino in a sub-order named by him the Sparassodonta, a group which he regards as referable neither to the creodonts, the placental carnivores, nor the carnivorous marsupials. That the so-called Sparassodonta are true marsupials, and not worthy of sub-ordinal rank, is fully apparent from the following characters, which they possess in common with existing marsupial carnivores:

1. A typical marsupial dental formula, $\frac{4-3}{3}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{4}{4}$.

2. The number of successional teeth is reduced below that characteristic of the placentals.

3. The nasals are broad posteriorly, excluding from contact the frontals and maxillæ. There is usually a small contact in existing carnivorous marsupials. A similar broadening of the nasals is observable in *Mesonyx*, *Harpagolestes* and *Dromocyon* among the Creodonta.

4. Anteroposterior shortening of basis cranii.

5. Lachrymal spreading out on the face; lachrymal duct within the orbit. An internal opening of the lachrymal duct is observable in *Thylacynus*.

6. Inflected mandibular angle.

7. Excavation of the premaxillæ for reception of the tips of the lower canines as in the dasyures, *Thylacynus* and the opossums.

8. Basisphenoid and alisphenoid ridged as in existing marsupial carnivores and unlike the structure of this region in the placentals.

9. Posterior extension of the malar bar to form the pre-glenoid process.

10. Posterior border of palate thickened. This structure is observable also in certain creodonts.

11. Posterior border of palate perforated by a large foramen on either side of the posterior nares.

12. An alisphenoid bulla present in some genera, absent in others. Tympanic annular and unfused with the adjacent elements in the former, unknown in the latter.

13. Basisphenoid perforated by internal carotid artery.

14. Presence of a vascular foramen (the post-zygomatic of Cope) perforating anteriorly the base of the zygoma below or within the lip of the post-glenoid foramen.

15. Presence of a large vascular foramen (the sub-squamosal of Cope) perforating the squamosal on or above the crest which connects the base of the zygoma with the inion. This is absent in the placental carnivores.

16. Sutures of the skull distinct. Not strictly a marsupial character, but indicative of marsupial affinities when considered in connection with the other characters presented.

The four best known genera may be arranged as follows:

A. Skull brachycephalic. Alisphenoid not dilated to form an auditory bulla.

1. Dental formula $\frac{4}{3}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{4}{4}$. Protocone on upper molars reduced. M^4 biscuspidate with paracone and antero-external style. Posterior premolars greatly enlarged. Talonid of M_4 with single conical cusp. Terminal phalanges round, blunt, and broadly fissured at the tips.

B. Skull dolichocephalic. *Borhyæna.*

(*a*) Alisphenoid bulla absent.

1. Dental formula $\frac{4?}{3}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{4}{4}$. Protocone well developed on M^1 and M^2, reduced on M^3. M^4 with vestigial protocone and metacone. Posterior premolar not greatly enlarged; in the inferior series not exceeding the median premolar in size. Talonid of M_4 small and basin-shaped. Terminal phalanges laterally compressed, sharply pointed, and slightly cleft at tips. *Prothylacynus.*

(*b*) An alisphenoid bulla.

1. Dental formula $\frac{4}{3}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{4}{4}$. Protocone well developed on M^{1-3}. M^4 with small conical protocone, large paracone and antero-external style; metacone reduced to the merest vestige or absent. Premolars increasing regularly in size posteriorly in both upper and lower series. Talonid of M_4 enclosing a small basin-shaped area, unicuspidate. Terminal phalanges uncleft, laterally compressed and pointed. *Cladosictis.*

2. Dental formula $\frac{4}{3}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{4}{4}$. Protocone well developed on all the upper molars. M^4 with protocone enclosing a basin-shaped area; paracone and antero-external style large; metacone vestigial or absent. Upper premolars increasing regularly in size posteriorly; median and posterior lower premolars subequal. Talonid in M_4 large and strongly bicuspidate. Terminal phalanges laterally compressed and pointed without clefts. *Amphiproviverra.*

The Santa Cruz thylacynes are short-legged animals with large heads, long necks and heavy tails. These characters are well shown in the accompanying restorations of *Prothylacynus patagonicus* and *Cladosictis lustratus* (Plates I and II) reproduced from the forthcoming Volume IV of the Reports of the Princeton University Expeditions to Patagonia. In addition to the characters already mentioned, the following are worthy of notice:

1. The facial region of the skull is short in proportion to the length of the cranium. The brain case is small and greatly constricted postorbitally. The orbits are placed much further forward than in the Dasyuridæ, opossums, or *Thylacynus*. The jugal arches are robust and broadly expanded, and the sagittal and lambdoidal crests well marked but not very high. The palate lacks the vacuities present in all existing carnivorous marsupials, but is perforated by a number of accessory palatine foramina. Between the molars, the margin of the palate is depressed into deep hemispherical fossæ for reception of the tips of the lower teeth when the mouth is closed. The occiput is semicircular in outline in contrast with its triangular shape in the dasyures, *Sarcophilus* and *Thylacynus*. The lachrymal canal opens well within the orbital rim. In the majority of living marsupials, the opening of the lachrymal duct is placed either on or external to the orbital rim. *Thylacynus* is transitional between these two types of structure in that it possesses a double lachrymal perforation, one branch of the canal opening without and the other within the orbit. *Borhyæna* and *Prothylacynus*, resemble *Sarcophilus* in the fusion of the mandibular symphysis. In the remaining genera the symphysial union is ligamentous.

2. The molars are of the same type as in *Thylacynus*, differing principally in the greater reduction of $M\frac{4}{}$, the loss of all the styloid cusps except the antero-external, and the character of the heel of the last lower molar, which may be either small and conical, basin-shaped or bicuspidate. The premolars are unreduced in number, and usually increase in size posteriorly in both series. The canines are long, sharply pointed and slightly curved in the smaller genera. In *Borhyæna* the fang is swollen and the point short and blunt. The incisors in *Borhyæna* are reduced to $\frac{3}{3}$, an exceptional formula among marsupials in that the number above and below is the same. In *Amphiproviverra* the median pair are conical and approximated at the tips as in *Dasyurus* and *Didel-*

phys. The posterior premolar is preceded, in *Cladosictis*, by a deciduous tooth resembling the first molar. According to Ameghino, the median premolar and canine in this genus also have deciduous predecessors, and in *Borhyæna* the canine is said to displace a deciduous tooth.

3. The atlantal intercentrum is unfused with the base of the neural arch in *Borhyæna* and *Amphiproviverra*, as it is also in *Thylacynus*. In *Prothylacynus* and *Cladosictis* complete fusion has taken place with obliteration of the sutures. An atlantal foramen for the transmission of the spinal nerve and vertebral artery is present in all the genera except *Borhyæna*, which resembles *Phascolomys* in transmitting the nerve and artery through a groove in the anterior margin of the neural arch. The axis carries a large hatchet-shaped neural spine. The bases of the transverse processes of the second to the seventh cervicals are perforated for the transmission of the vertebral artery. The dorso-lumbar vertebral formula was probably nineteen as in *Thylacynus:* thirteen dorsals and six lumbars. As in that genus, the anticlinal vertebra is the tenth dorsal. Two vertebræ are coössified in the sacrum. The tail was undoubtedly long, very heavy and greatly thickened at the base.

4. The limbs are short in proportion to the length of the body and the feet small with spreading toes. The trochlear surface of the astragalus is short and flat with feebly differentiated facets for the tibia and fibula which latter articulates with the calcaneum. In *Prothylacynus*, the hallux is reduced to a deformed metatarsal, which carries no phalanges and terminates distally in a blunt rounded knob. In *Cladosictis*, the hallux is small, judging from the size of its articulation on the entocuneiform. It may have supported phalanges. The hallux in *Amphiproviverra* is large and opposable indicating that this genus was probably arboreal. The pollex is known in *Amphiproviverra* and *Cladosictis*. In these genera, the phalanges of the pollex are deflected toward the inner side of the foot as a result of the enlargement of the outer condyle of the metacarpal of the thumb. In gait, the Santa Cruz thylacynes were probably plantigrade. In striking contrast with these extinct genera the pes of *Thylacynus* shows a peculiar cursorial modification. Not only is the gait of this animal digitigrade, and the hallux entirely obliterated, but the ectocuneiform has shifted toward the outer side of the foot until it is supported almost entirely by the

cuboid. In the Santa Cruz forms, this shifting has progressed to about the same extent as in *Sarcophilus*. There is no trace of syndactyly. The manus and pes are pentadactyl in *Amphiproviverra* and *Cladosictis*. The manus is pentadactyl in *Borhyæna* and probably also in *Prothylacynus*. The hallux is reduced to a vestige in the latter genus. Its condition in *Borhyæna* is unknown.

5. The pelvis is without trace of epipubic ossifications in *Cladosictis*. The pubes are not preserved in the only specimen of *Prothylacynus* in the Princeton collection, and the pelvis of *Borhyæna* and *Amphiproviverra* is unknown. The patella is ossified in *Amphiproviverra* and *Prothylacynus*. The radius and ulna are capable of some degree of pronation and supination. The tibia and fibula are unfused. The inner humeral epicondyle is perforated by a large foramen in *Prothylacynus* and *Cladosictis;* imperforate in *Amphiproviverra*. The supinator ridge terminates in a hook-shaped extremity in *Prothylacynus*. This is wanting in *Amphiproviverra* and *Cladosictis*.

THE DIDELPHYIDÆ.

The Didelphyidæ are represented in the Santa Cruz fauna by several genera of which *Microbiotherium* is the best known. In dental formula and the structure of the lower molars *Microbiotherium* agrees with *Didelphys*, differing from all the opossums in the greater reduction of the outer cingulum, styloid cusps, and metacone spur in the upper molars. The posterior premolar is enlarged in both the upper and lower dental series. The premolars are double-rooted in the majority of the species and decrease in size anteriorly. The molars in both series decrease in size posteriorly as in the existing didelphyd genus *Caluromys*.

THE CÆNOLESTIDÆ.

This family, better known as the Epanorthidæ, includes all the Santa Cruz diprotodont marsupials. As the genus *Palæothentes*, defined by Ameghino in 1887, has priority over *Epanorthus*, proposed by him two years later, necessitating the rejection of the latter, the family has been renamed after its best known representative, *Cænolestes*. All the members of this family are small animals and are very incompletely known.

Three subfamilies may be recognized. The more primitive members of the first of these, the Cænolestinæ, form a connecting

link between the polyprotodont and diprotodont marsupial suborders in possessing, in the lower jaw, the tuberculo-sectorial type of molar characteristic of the polyprotodonts combined with a diprotodont modification of the median incisors. One of the minute Santa Cruz forms has the same inferior dental formula as the opossums. Unfortunately, nothing is known of the upper dentition, skull and feet of this important transitional form.

The second subfamily, the Palæothentinæ, contains the largest of the Santa Cruz diprotodonts. The upper molars of the Palæothentinæ resemble closely those of certain bunodont phalangers. The first is fully quadritubercular. The second has a rudimentary hypocone. The third and fourth are tritubercular. The lower molars are lophodont. The posterior upper premolar and first lower molar are modified as sectorial teeth. The dental formula varies in the different genera but there are always four molars above and below. The members of this subfamily form a regular progressive series in the shortening of the anterior portion of the mandible and the reduction of the posterior lower premolar from a double-rooted fully functional tooth to a single-rooted more or less vestigial condition.

The Abderitinæ, the third subfamily, are the most specialized of the Santa Cruz diprotodonts. The first lower molar is greatly enlarged, vertically grooved, and notched along the cutting edge of the crown, resembling in some respects the peculiar sectorial teeth of the multituberculate Plagiaulacidæ. The sectorial in *Abderites*, however, possesses a large bicuspidate heel, which is lacking in the Plagiaulacidæ, and the remaining molars are quadritubercular.

The Cænolestidæ are examples of the restrictive influence of competition on adaptive radiation. During the Santa Cruz epoch they were crowded into obscurity by a horde of placentals, sloths, rodents, and ungulates, and had no opportunity to attain the high degree of adaptive specialization shown by the Australian diprotodonts, although so far as can be judged, they possessed as much latent capacity toward variation as do their nearest living allies, the phalangers.

RELATIONSHIPS OF THE SANTA CRUZ MARSUPIALS.

The Patagonian thylacynes do not represent the main line of descent which ended in *Thylacynus*. In all the Santa Cruz genera

the last upper molar has undergone greater reduction and the styloid cusps have decreased in number, the antero-external alone being represented. Apart from these advanced characters in the dentition, the Santa Cruz thylacynes are of a distinctly more primitive type than their surviving Tasmanian relative, which has progressed in the lengthening of the face and posterior shifting of the orbit, the increased brain capacity, the acquisition of palatal vacuities, the prenatal shedding of the deciduous teeth, the external shifting of the outer cuneiform, and the loss of the hallux. With the exception of the reduced hallux in *Prothylacynus*, transitions to these advanced types of structure do not appear in the Santa Cruz members of the family.

The marsupial faunas of those formations in Patagonia older than the Santa Cruz are still too imperfectly known to afford a secure basis for phylogenetic speculation, but it may confidently be expected that the common ancestor of *Thylacynus* and the extinct Santa Cruz types will be found among them. In fact, certain large carnivorous marsupials from the Pyrotherium beds named by Ameghino, *Proborhyæna* and *Pharsophorus* retain the metaconid in the lower molars as in the Dasyuridæ, while the premolar formula is unreduced as in the Thylacynidæ.

The affinities of *Microbiotherium* are unquestionably didelphyd. The genus can not be regarded as ancestral to any of the existing South American opossums as the degree of reduction of the external cingulum and styloid cusps in the upper molars is greater.

The most primitive of the Cænolestidæ, the genus *Halmarhiphus*, is transitional to the Polyprotodontia and represents, with little or no modification, a type which is not only ancestral to the Palæothentinæ but agrees perfectly with the "minute insectivorous forms which, apart from the diprotodont modification of the antemolar teeth, possessed a full antemolar formula," indicated by Bensley's[1] studies as the ancestors of the Phalangerinæ. Unfortunately this interesting transitional genus is known only from the lower jaw. The Palæothentinæ are important in retaining constructive stages in the evolution of the bunodont type of molar characteristic of the more primitive of the existing phalangers. The Abderitinæ are highly specialized diprotodonts which appear

[1] Bensley, B. A., "The evolution of the Australian marsupials, etc.," *Trans. Linn. Soc., London*, ser. 2 (Zoöl.), vol. 9, p. 139, 1903.

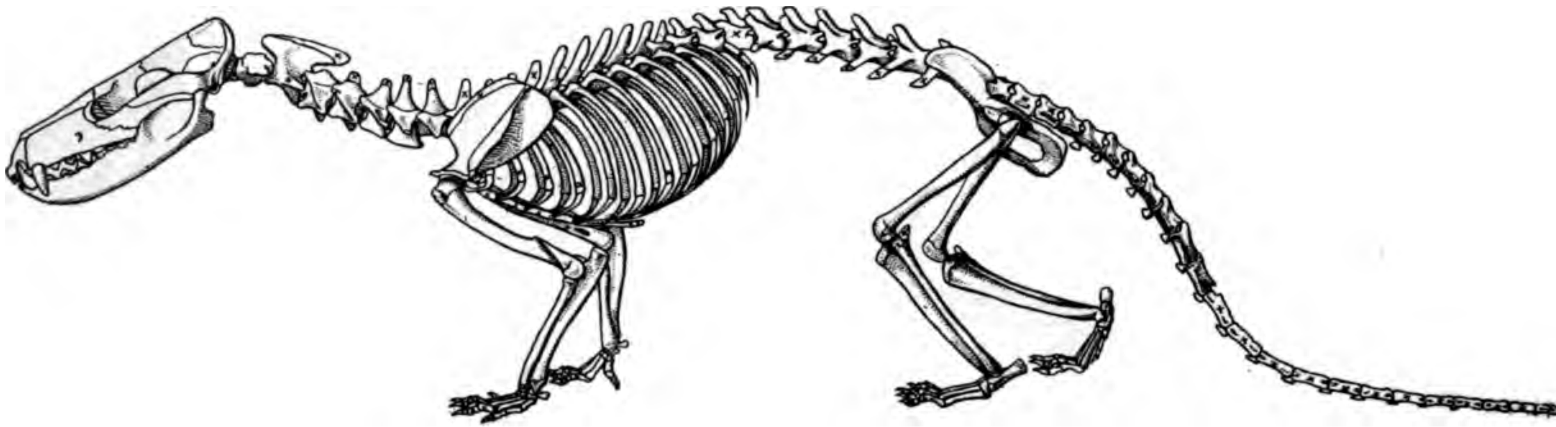

PLATE I. Cladosictis lustratus, × about $\frac{1}{4}$.

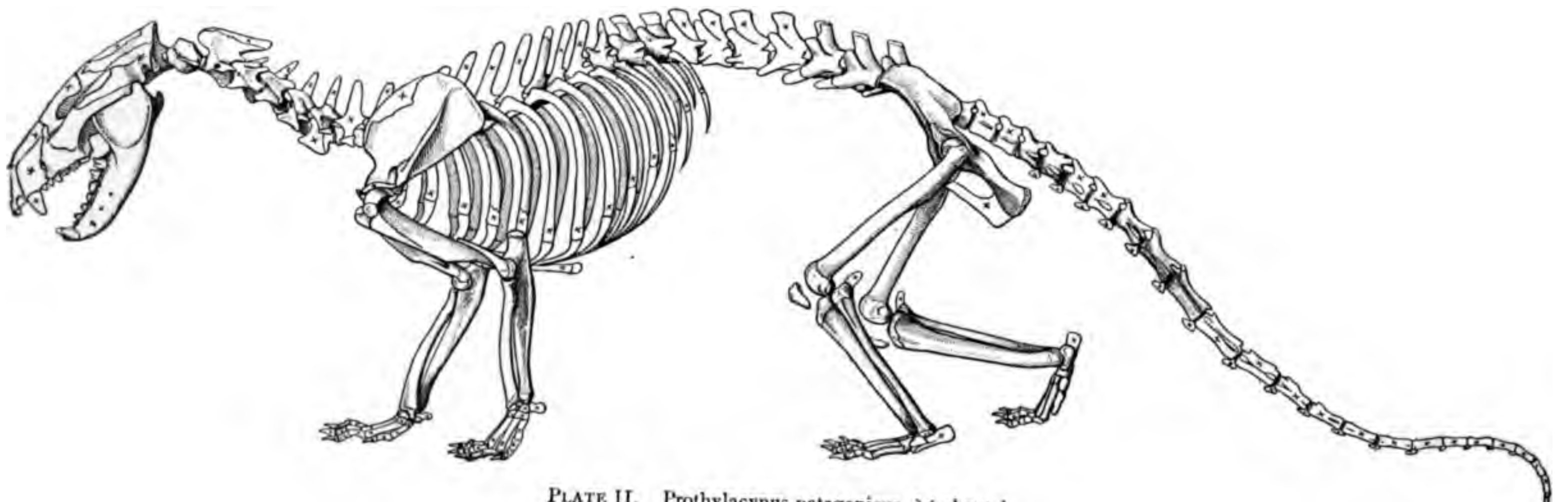

Plate II. Prothylacynus patagonicus. $\times$ about $\frac{1}{8}$.

to have become extinct with the Palæothentinæ at the close of the Santa Cruz epoch, while the less specialized Cænolestinæ were able to persist to the present day.

The Cænolestidæ resemble the primitive phalangers in so many respects that it is impossible to escape the conclusion that the two families are related and not merely convergent groups. With the exception of *Halmarhiphus*, a persistent ancestral type, the Santa Cruz diprotodonts possess specializations in dental structure which prevent their being regarded as direct ancestors of the phalangers, but favor the idea that both groups are descended from a common ancestry.

Considerable evidence is now available to show that a land connection between Patagonia and the Australian region existed not later than the close of the Cretaceous or beginning of the Tertiary[1] and it is possible that at this time the interchange of marsupials between the two continents was effected. Whether the marsupials originated in South America and migrated thence to Australia, or the reverse, can not at present be demonstrated, but a South American origin for at least some of the existing Australian and Tasmanian types appears probable in view of their unmistakable relationships with Santa Cruz forms.

PRINCETON UNIVERSITY, April, 1905.

EXPLANATION OF PLATES.

PLATE I. *Cladosictis lustratus.* Restoration based upon two specimens in the collection of Princeton University. The skeleton measures 3 feet over all. Restored parts are indicated by a cross.

PLATE II. *Prothylacynus patagonicus.* Restored from a single specimen in the Princeton collection. The skeleton measures 4 feet 8¼ inches over all. The restored parts are indicated by a cross.

[1] For a summary of the evidence see Ortmann, *Reports of the Princeton University Expeditions to Patagonia*, Vol. IV, pp. 310–324.

THE STRAIGHT LINE CONCEPT.

BY P. A. LAMBERT.

(*Read April 14, 1905.*)

INTRODUCTION.

The foundation of a science is the system of assumptions which gives precision to the concepts with which the science deals. It is essential that the system of assumptions together with the results obtained by applying the processes of logic to the concepts shall be free from contradiction. This freedom from contradiction is generally established by showing that the system of assumptions gives precision to some complete number system of arithmetic.

It is an important problem in any science to reduce the system of assumptions to a minimum. This problem is solved by excluding all assumptions which are logical consequences of other assumptions. When the system of assumptions of a science is reduced to a minimum the omission of any one assumption or the change of any one assumption will either lead to a contradiction or change the concepts of the science.

In order that a science shall not become a mere exercise in mental gymnastics the results obtained by applying the processes of logic to the concepts of the science must agree with observed results in the processes of the physical world.

The assumptions of a science are also called the axioms of a science. The assumptions of geometry are called axioms by Hilbert in the Grundlagen der Geometrie.

THE STRAIGHT LINE.

The logical entities with which rational geometry deals are the concepts named the point, the straight line and the plane. Precision is given to these concepts by axioms which have been arranged by Hilbert in five groups, called axioms of relation, axioms of order, axioms of congruence, axioms of parallels and axioms of continuity.

The importance of the straight line, whether by straight line we understand the intuitive entity of experience or the logical entity

of rational geometry, depends primarily on the fact that a straight line is determined by any two of its points and can be indefinitely extended between any two of its points. Right here arises a question that can not be answered by experience or experiment. If the straight line is indefinitely extended beyond any two of its points, will there be found on the straight line two points at infinity, one point at infinity, or no point at infinity? This question, of course, can not be answered until precision has been given to the term distance.

In the plane determined by a given point and a given straight line, draw a straight line through the given point intersecting the given straight line and revolve the straight line about the given point. When the point of intersection of the revolving line with the given line moves to an infinite distance from the foot of the perpendicular from the given point to the given line, the revolving line is said to become parallel to the given line. In how many positions does the revolving line become parallel to the given line? This, again, is a question that can not be answered by experience or experiment. It can be answered only by the axiom of parallels.

If the axiom of parallels is made to read: Through a given point without a given line one and only one parallel to the line can be drawn — we have a geometry in which the straight line has only one point at infinity. This is the geometry of Euclid. Since the parabola meets the straight line at infinity in only one point, this geometry is also called the parabolic geometry.

If the axiom of parallels is made to read: Through a given point without a given line two and only two parallels to the line can be drawn — we have a geometry in which the straight line has two and only two points at infinity. Since the hyperbola intersects the straight line at infinity in two points, this geometry is called the hyperbolic geometry. The hyperbolic geometry was developed by Euclidean methods by Lobachevski and Bolyai.

If the axiom of parallels is made to read: Through a given point without a given line no parallel to the line can be drawn — we have a geometry in which the straight line has no point at infinity. Since the ellipse does not intersect the straight line at infinity in a real point, this geometry is called the elliptic geometry. The elliptic geometry has been discussed by Riemann, Clifford and Newcomb.

THE EXPRESSION FOR DISTANCE.

Much of the apparent mystery of hyperbolic and elliptic geometry vanishes when precision is given to the term distance. Distance is the result of measurement, and the measurement of a straight line requires that any part of the straight line may be applied anywhere along the straight line. If A, B, C are any three points in a straight line, and B is between A and C, the expression for distance must satisfy the equation

$$\text{distance } AB + \text{distance } BC = \text{distance } AC.$$

In a system of measurement introduced by Cayley in the Sixth Memoir on Quantics and developed by Klein, the expression for the distance between two points on a straight line is a function of the cross-ratio of these two points and two fixed points on the straight line. Let the fixed points be X, Y and A, B, C any three points taken in order on the straight line. By definition the cross-ratio of the four points A, B, X, Y is

$$(AX) / (AY) \div (BX) / (BY).$$

It follows from this definition that:

cross-ratio $ABXY \times$ cross-ratio $BCXY =$ cross-ratio $ACXY$.

Applying logarithms to this equation

$$\log \text{cross-ratio } ABXY + \log \text{ cross-ratio } BCXY = \text{log-cross-ratio } ACYX.$$

The expression

$$k \log \text{cross-ratio } ABXY$$

where k denotes any constant may therefore be taken as the expression for the distance between the points A, B.[1]

The pair of fixed points X, Y is called the absolute of linear measurement. When one of the points A, B coincides with a point of the absolute the distance AB becomes infinite. Hence when the absolute consists of two distinct real points, the straight line has two points at infinity; when the absolute consists of two coincident points, the straight line has one point at infinity; when

[1] The constant k must be so determined that the expression for distance has a real value. Since the logarithm is a many-valued function for which the series of values differ by multiples of $2\pi\sqrt{-1}$, when k is imaginary the expression for distance is a many-valued function for which the series of values differs by multiples of some real constant.

the absolute consists of a pair of imaginary points, the straight line has no point at infinity.

In the geometry of two dimensions the absolute must be the locus of the point pairs which are the absolute of all the lines in the plane. It follows that the points on the absolute are the points at infinity in the plane. By substituting in the equation of the absolute $f(x, y) = 0$ for x and y respectively $(x_1 + \lambda x_2)/(1 + \lambda)$ and $(y_1 + \lambda y_2)/(1 + \lambda)$ there will be found two values of λ, say λ_1 and λ_2, to which correspond the points of intersection of the straight line through the points (x_1, y_1) and (x_2, y_2) with the absolute, and the cross-ratio of the points (x_1, y_1), (x_2, y_2) and the points of intersection with the absolute is λ_1/λ_2. This cross-ratio is therefore readily calculated whether the points of intersection are real or imaginary.

If the equation of the absolute in homogeneous coördinates is $x^2 + y^2 - 4a^2t^2 = 0$, in order that the distance between two points within the absolute shall be real the constant k must be real. Every straight line determined by two points within the absolute has two points at infinity and we have the hyperbolic geometry of two dimensions. Points without the absolute are non-existent in this geometry.

If the equation of the absolute in homogeneous coördinates is $x^2 + y^2 + 4a^2t^2 = 0$ the constant k must be assumed imaginary in order that the distance between two points of the plane shall be real. The straight line has no point at infinity and we have the elliptic geometry. In this geometry the straight line has a finite length and must return into itself. The distance between two points has a series of values differing by multiples of the length of the entire straight line.

The points whose homogeneous coördinates are $x = 1$, $y = \sqrt{-1}$, $t = 0$; $x = 1$, $y = -\sqrt{-1}$, $t = 0$ satisfy the equations of the absolute in both the hyberbolic and elliptic geometries. These two points, named the imaginary circular points at infinity, constitute the absolute of plane parabolic geometry. The parabolic geometry is therefore a common limiting case of the hyperbolic and elliptic geometries. By a suitable choice of the constant k the parabolic geometry becomes the geometry of Euclid.

In the geometry of three dimensions the absolute of hyperbolic geometry may be written $x^2 + y^2 + z^2 - 4a^2t^2 = 0$; the absolute

of elliptic geometry $x^2 + y^2 + z^2 + 4a^2t^2 = 0$; the absolute of parabolic geometry, $x^2 + y^2 + z^2 = 0$, $t = 0$, again a common limiting case of the absolute of hyperbolic and elliptic geometry.

By taking a in the equation of the absolute sufficiently large the hyperbolic and elliptic geometries approach identity with the parabolic geometry in finite regions of space, so that experience or experiment can never determine that the space of experience is hyperbolic, elliptic or parabolic.

The expression for the distance between two points must satisfy the requirement that the distance between two points shall be the same for all positions of the straight line on which the two points are located. A collinear motion of space into itself is represented analytically by a linear transformation which transforms the absolute into itself. The cross-ratio is an invariant of linear transformations. Hence the definition of distance $k \times$ log cross-ratio satisfies also this requirement of the expression for distance.

By the calculus of variations it is proved that in the elliptic, hyperbolic and parabolic geometries the straight line is the shortest distance between two points. Hilbert, by taking for absolute a triangle, has proved that the sum of two sides of a triangle may be equal to or less than the third side.

ANGLE MEASUREMENT.

In Cayley's system of measurement the measure of an angle is defined as a constant times the logarithm of the cross-ratio of the pencil of four rays formed by the sides of the angle and the tangents to the absolute from the vertex of the angle. If the equation of the absolute in line coördinates is $f(u, v) = 0$, the measurement of angles about the point of intersection of the lines (u_1, v_1) and (u_2, v_2) is analytically identical with the measurement of distance on a line through two points.

It follows from the definition that a right angle is an angle whose sides are harmonic conjugates with respect to the tangents from the angle vertex to the absolute. In the hyperbolic geometry any line through the pole of a given line with respect to the absolute intersecting the given line is perpendicular to it; the angle between lines intersecting on the absolute is zero, hence the two lines drawn from a given point to the intersections of a given line with the absolute are parallel to the given line; the sum of the angles of a triangle is less than 180°.

The chief attraction of hyperbolic geometry lies in the fact that one has the power to see the whole of hyperbolic space and to direct geometric constructions from a vantage point outside of this space. For example, to draw a common perpendicular to two straight lines, not intersecting and not parallel, connect by a straight line the poles of the given straight lines with respect to the absolute. This problem has been solved by Hilbert by methods such as a being living in hyperbolic space would be obliged to use. It is a simple matter to determine directly from the expression for distance that the locus of points in the hyperbolic plane equidistant from a given straight line is an ellipse tangent to the absolute where the given line meets the absolute.

GEOMETRY ON SURFACES OF CONSTANT TOTAL CURVATURE.

If R_1 and R_2 are the maximum and minimum radii of curvature of the normal sections of a curved surface at any point of the surface, the reciprocal of the product of R_1 and R_2 is called the Gaussian or total curvature of the surface at this point. The geometry of geodesics on surfaces whose total curvature is constant has striking analogies to plane Euclidean geometry. Euclid's definition of a straight line as a line which lies in the same manner with respect to all the points in the line, and his definition of a plane as a surface which lies in the same manner with respect to all straight lines in the plane, when taken in connection with Euclid's "Common Notions" implies the congruent displacement of a straight line into itself, that is the displacement of the straight line into itself such that any two points of the line may be made to coincide with any other two points of the line provided the distance between the first pair of points equals the distance between the second pair; and the congruent displacement of the plane into itself, that is the displacement of the plane into itself such that any portion of the plane bounded by straight lines may be made to coincide with any other portion provided the two portions are bounded by straight lines of equal length and the corresponding angles are equal. Now surfaces whose total curvature is constant and geodesics on these surfaces also possess this property of congruent displacement, provided displacement is suitably defined.

If the constant total curvature of the curved surface is $-a^2$, the geometry of geodesics on the curved surface is identical with the

geometry of the plane with hyperbolic measurement.[1] The type of surfaces with constant negative total curvature is the pseudosphere of revolution, generated by revolving the tractrix about its asymptote.

If the constant total curvature of the curved surface is $+ a^2$, the geometry of geodesics on the curved surface is identical with the geometry of the plane with elliptic measurement.[1] The type of curved surfaces with constant positive total curvature is the sphere. It is important to note that the entire elliptic plane is represented on the hemisphere.

These statements show the reasonableness of using as equivalent the terms elliptic space and space of positive curvature; hyperbolic space and space of negative curvature; parabolic space and space of zero curvature.

CONTINUITY OF THE STRAIGHT LINE.

It remains to examine the elemental structure of the straight line. Adopting as definition of continuity the totality of all real numbers, is the totality of distances from a fixed point of the line to all other points of the line continuous? This question must be answered by establishing a correspondence between sets of numbers and points and lines, that is by a system of analytic geometry.

Let any pair of numbers (x, y) correspond to a point, any pair of numbers (u, v) correspond to a straight line, and let the equation $ux + vy + 1 = 0$ denote that the point (x, y) is on the line (u, v). The straight line is now determined by any two points and two straight lines intersect in only one point, that is, the straight line is the straight line of Euclid. If x, y and u, v are any numbers of the totality of numbers obtained from unity by applying a finite number of times the operations addition, subtraction, multiplication, division and taking the positive square root of unity plus the square of any number previously determined, Hilbert has proved that all the constructions of Euclid are possible. The straight line, however, is clearly not continuous, for no transcendental numbers occur in the totality of numbers represented on the straight line.

The continuity of the straight line is not a necessity of Euclid's

[1] Except for certain self-evident limitations due to the peculiarities of the surface.

geometry, it is not an intuitive property of the straight line and it cannot be proved by experiment. The continuity of the straight line can be established only by means of axioms, whether these axioms take the form given by Dedekind in his Essays on Number or by Hilbert in his Foundations of Geometry. When the continuity of the straight line has been established the Cartesian geometry at once follows.

LEHIGH UNIVERSITY,
April 8, 1905.

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1905

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VOL. XLIV. MAY–JULY, 1905. No. 180.

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PHILADELPHIA

THE AMERICAN PHILOSOPHICAL SOCIETY

104 SOUTH FIFTH STREET

1905

GENERAL MEETING—1906

The next General Meeting of the Society will be held on April 17–20, 1906, beginning on the evening of Tuesday, April 17.

Wednesday, April 18, will be devoted to the presentation and discussion of scientific papers, and Thursday, 19, and Friday, 20, to the ceremonies connected with the celebration of the 200th Anniversary of the Birth of Benjamin Franklin.

Members desiring to present papers on subjects of science at the General Meeting are requested to communicate with the Secretaries at the earliest possible date.

CORRIGENDUM

In No. 179 the volume number should be corrected to read Vol. XLIV.

A new title page, containing the correct volume number, to be substituted for the one in No. 179, will appear in the concluding number of this volume.

Members who have not as yet sent their photographs to the Society will confer a favor by so doing; cabinet size preferred.

It is requested that all correspondence be addressed

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VOL. XLIV. APRIL–MAY, 1905. No. 180.

THE MUTUAL AFFINITIES OF THE SPECIES OF THE GENUS CAMBARUS, AND THEIR DISPERSAL OVER THE UNITED STATES.

(PLATE III.)

BY DR. A. E. ORTMANN.

(Read April 13, 1905.)

In a previous study of the geographical distribution of the crayfishes of the United States (see *Proc. Amer. Phil. Soc.*, xli, 1902, pp. 277–285), the present writer took it for granted that the division of the genus *Cambarus*, into five groups, as introduced by Faxon (*Mem. Mus. Harvard*, 10, 1885), and the arrangement of the species within each group adopted by him, would correspond, as far as one might expect, to the natural affinities.

This, however, is true only to a certain degree. There is no doubt that Faxon correctly recognized the chief systematic groups within the genus, and that he also had, in most cases, appropriate views as to the relationship of smaller groups of species. But accepting his system as a whole, and trying to correlate it with the peculiarities shown by the geographical distribution, a number of cases are revealed, where such a correlation is not very apparent, and attempts to give a reasonable theoretical explanation prove to be more or less unsatisfactory. I shall mention here a few instances.

1. The fifth group of the genus follows, in Faxon's system, after

the fourth, and he apparently believes, that it is connected genetically with the latter. The geographical distribution, however, is opposed to this assumption, and a closer study has led me to think that there is no such affinity between these two groups, and that the fifth is more closely allied to the first and second. (Compare Ortmann, *l. c.*, 1902, p. 283.)

2. Faxon believes (*l. c.*, 1885, p. 19) that the first group contains the most primitive forms. This is not probable when we consider the very highly specialized character of most of the species. Indeed, there are rather primitive forms among them, but they are clearly not as primitive as certain species of the second group (Ortmann, 1903, p. 283), and further, the main range of the first group occupies a territory that is, geologically, comparatively young, namely, the lowlands of the southern states (Mississippi, Alabama, Georgia, Florida), of which we know that they became land by degrees during the Tertiary period, the more southern parts in very recent times. It is not very likely that this recent land is occupied by an ancient group of animals.

3. I strongly object to placing *Cambarus pellucidus*, the blind cave-species of Kentucky and Indiana, with the first group, where it stands entirely isolated, morphologically as well as geographically. If we place this species at the beginning of the fourth group, it comes into an assemblage, from which it is not so strongly different. It will always remain a remarkable, and, as Faxon believes, a primitive type, but it is not *the most primitive* type of the genus in all respects. In the shape of the male organs it certainly points rather to the fourth group than to the first.

4. Faxon places *C. blandingi* at the head of the genus: this is apparently due to the desire to let the type-species of the genus stand first. This, however, may convey the wrong impression, that *C. blandingi* is the lowest (or else the highest) form of the whole genus. But I do not think that it is either, and regard it as a highly specialized (but not *the most highly* specialized) form of a branch of the genus that is rather ancient. The distribution of *C. blandingi* has all the characters of a comparatively modern encroachment upon foreign territory.

5. I believe that the second group of Faxon contains the most primitive types of the genus. But this is to be understood "cum grano salis." There are, in this group also some very highly

specialized types (*C. gracilis* and allies), and even some of the primitive forms (*C. cubensis*) possess some peculiar and apparently advanced characters. I think we can express it this way: among the second group, there are species that approach most closely the original stock of the genus, but they themselves are modified to a degree. If I am to single out a species that possibly is *the* most primitive, I should name *C. digueti* Bouvier (*Bull. Mus. Paris*, 1897, p. 224), which is identical with *C. carinatus* Faxon (*Pr. U. S. Mus.*, 20, 1898, p. 648). It is remarkable that the most primitive forms are found in Mexico (and Cuba), which agrees well with the theory of the origin of the genus in these parts (see Ortmann, *l. c.*, 1902, p. 283).

CHARACTERS OF THE GENUS CAMBARUS THAT SERVE TO DISTINGUISH GROUPS AND SPECIES.

Sexual Organs.—Already the earlier writers (Girard, Hagen) have pointed out the importance of the anterior pair of abdominal appendages of the male (copulatory organs) for systematic purposes. Faxon made large use of them in defining his five groups, but within the groups he rarely tried to avail himself of these limbs to reveal the mutual affinities of the different species. It is now generally known that these organs furnish not only the best specific characters, but that their similarity in certain assemblages of species clearly indicates genetic relationship. In close connection with the shape of this organ is that of the female "annulus ventralis," as we now know, the receptaculum seminis. There is, however, not so much variety in the shape of the latter organ, it is not so polymorphous, and the main types occur in different groups, which is apparently due to the more simple structure of this organ. Nevertheless, the annulus—in connection with the male organ—is rather important. We may add that in a number of species the annulus is not very well known.

As regards the male organs, their shape is very complex and much varied. Several main types may be distinguished, and these again show much diversity. It is hardly likely that in so complex an organ the identical form has developed several times, that is to say that there are cases of parallelism; where there is identity or similarity of these organs in different species, this is generally and surely a sign of close affinity. Only one or two exceptions in the

first and second group are known to me, where the question is admissible, whether convergency plays a part. There are rarely two species known, where the shape of the male organs is absolutely identical (except in the third group of Faxon, where they are remarkably uniform), and since they have developed from the beginning in three or four different main lines, it is easily understood why they furnish the best specific characters as well as the best criteria for judging the affinities. Thus the danger of being misled by convergency of structure, which is the chief impediment of properly recognizing natural affinities in any group of animals, is here reduced to a minimum. We shall see below that by the actual use of this principle we arrive at conclusions that render the investigation of the development of the genus *Cambarus* a comparatively easy task, furnishing a clue to the explanation of the geographical distribution; further, the study of the male organs gives us a standard by which to judge the other characters that are of systematic value, and as we shall presently see, there is hardly another structure that has the same value for revealing the affinities within the genus, that is to say, the same characters generally develop independently in different groups, being clearly subject to parallelism, presumably under the influence of similar external conditions. In a few cases the latter is very evident.

Copulatory Hooks of the Male.—Faxon lays much stress upon the number of hooks present in the male on the ischiopodite of the second, third, or fourth pereiopods, which are used to take hold of the female in copulation. The third pereiopods always possess these hooks, and in many cases only this pair is present. But sometimes there is an additional pair on the second, or on the fourth pereiopods. The number of pairs of hooks is very constant in the single species (except for occasional abnormities), and it is remarkable that certain types of male sexual organs are generally connected with certain type of hooks; this is chiefly the case in the third, fourth and fifth group of Faxon, while it is not in the first or second, where similar types of sexual organs may be connected with different types of hooks.

If we consider that the presence of two pairs of hooks is certainly a more highly advanced stage than that of only one pair, that is to say, that the difference of the number of hooks is only a difference in the degree of development of one and the same feature, it

is easily conceivable that the increase of the number of hooks may have taken place independently in different groups, and we shall see below that there is at least one case (*C. pellucidus*), where we are to assume an independent origin of an additional pair of hooks on the fourth pereiopods; this is also rendered probable by the variability of this character seen in this species. That Faxon's fifth group has developed an additional pair of hooks independently is clearly shown by the fact that here it is the second pair of pereiopods that carries the additional hooks.

Indications of a more general tendency to increase the number of hooks are found in occasional freaks in other groups (*C. propinquus*, *C. virilis*).

General Shape of Carapace. — The primitive type of the carapace seems to be more or less ovate, generally depressed. It assumes, however, sometimes a more cylindrical form (in some cave-species), and in some cases it is rather compressed. The latter character is most remarkable in all burrowing species, and has developed independently at least in two groups (second and third of Faxon, *gracilis*- and *diogenes*-groups).

The *Areola* seems to be originally rather broad and short. But there is a general tendency of it to become narrower, and at the same time to increase its relative length. This is evidenced in almost all groups, and a narrow, sometimes partly obliterated areola is found in species that have nothing whatever to do with each other. In fact, it is only the fifth group of Faxon where this tendency is not manifested. Generally, the length of the areola is correlated to the width, but there are exceptions.

Rostrum. — The shape of the rostrum is characteristic for most species, but it is available only as a specific character. The original type seems to be a rather long rostrum, with more or less parallel margins, with a marginal spine on each side, and a rather long acumen. The chief tendency in further development is for the marginal spines to disappear, and for the whole rostrum to become shorter. This, however, is found in all five groups of Faxon in species which are not at all allied to one another. Even certain peculiar types of rostrum may reappear in a widely divergent group. Thus the *blandingi*-type is imitated, if the expression is permitted, by *C. immunis*, and the burrowing species possess all a rostrum of similar shape.

[It is very remarkable, that burrowing crayfishes of the southern hemisphere (*Parastacus defossus* Fax. from southern Brazil is at hand) resemble the North American burrowing species in a remarkable degree externally, chiefly so in the shape of carapace, rostrum, chelæ, length of abdomen, etc.]

The *Chelæ* are very variable in shape: they are fully developed only in old males, but generally quite characteristic for the species. One and the same type is often common to large groups of species, and thus they are often a good help in the investigation of the natural affinities. But in other cases a similar form of chelæ is found in different groups which is most striking again in the burrowing species.

Among the more primitive species the shape of the chelæ seems to be more or less subcylindrical, and rather elongated. This shape is found in Faxon's first, second, third, and fifth groups, but only in the first, second and fifth it is frequent. Removing *C. pellucidus* to the fourth group, also in the latter this type of chelæ is represented. In part of the second group, and in the third and fourth, a more or less ovate, broad, and depressed chela becomes common, but there is not much uniformity in detail, each group generally developing its own type.

The above are the more important characters. We see that all of them must be dealt with cautiously, if they are to be used for the investigation of affinities of species. Indeed, in many cases, they support the conclusions arrived at by the examination of the the sexual organs, but very frequently similarities of the above characters are due to convergency. The same is true of all other characters, such as armature of carapace, chelæ, shape of epistoma, antennal scales, of abdomen, telson, etc.

SUBGENERA OF CAMBARUS, ACCORDING TO THE CHIEF TYPES OF THE SEXUAL ORGANS OF MALE.

There are three chief types of the male sexual organs (first pair of abdominal appendages), the last of which is easily divided into two subtypes. According to these, I should like to distinguish four subgenera, as follows:

1. Subgenus: CAMBARUS (sens. strict.).

Sexual organs of male *stout*, more or less straight, and comparatively short, *truncated or blunt at the tip, the outer part ending in 1–3*

horny teeth, which are sometimes recurved, or compressed, or plate-like, and are *always sharply distinguishable from the blunt end.* Inner part terminated by a shorter or longer, acute spine, which is sometimes distinct from the tip of this part, so that it appears two-pointed. In the male the third or the third and fourth pereiopods have hooks.

2. Subgenus: CAMBARELLUS nov. subgen.

Sexual organs of male *stout*, straight, or slightly curved at the tips. *Outer part ending in two horny teeth*, which are rather long, taper rapidly, and are *not sharply distinguishable from the end, which is not truncated.* Inner part terminated by a rather long, acute spine. In the male, the second and third pereiopods have hooks.

[The two following subgenera represent the third type of male sexual organs, in which both parts, outer and inner, each terminate in *only one* tooth, which is rather slender, and *not sharply distinguishable* from the end, which is never truncated.]

3. Subgenus: FAXONIUS nov. subgen.

Sexual organs of male shorter or longer, *not very stout, generally slender*, or with slightly curved tips. *Tips never truncated, ending always in two more or less elongated spines*, the one formed by the outer part, and horny, the other formed by the inner part and softer. There is *never more than one tip to the outer part*, and there is no terminal tooth distinguishable, but the tip tapers gradually, or the whole outer part is setiform. In the male generally the third pereiopods only have hooks, very rarely (in *C. pellucidus*) hooks are found on third and fourth pereipods.

4. Subgenus: BARTONIUS nov. subgen.

Sexual organs of male very uniform throughout the subgenus. They are *short and thick*, inner and outer part each terminating in *only one short and thick spine*, tapering to a point. Both terminal spines are *strongly recurved*, forming with the basal part about a right angle. In the male, only the third pereiopods possess hooks.

Subgenus: CAMBARUS. (Type: *C. blandingi.*)

This subgenus comprises Faxon's first and second group, excluding the species *C. pellucidus*. Both groups are rather heterogeneous, and so is this subgenus, and there are considerable variations in the male sexual organs. The chief feature of the latter is their blunt

ending, a character that possibly points to the condition seen in the genus *Potamobius*; for the rest, the terminal teeth are quite variable, but always very characteristic for the species.

It is advisable to distinguish groups within this subgenus, not only with reference to the sexual organs, but also with reference to the hooks of the male, for the presence of one or two pairs of hooks seems to constitute, as already Faxon recognized, important differences, the presence of two pairs, on third and fourth pereiopods, being evidently a more advanced stage. Using in addition some other differences of the areola and the chelæ, we obtain the following three sections.

1. Section: C. digueti.

Sexual organs of male with one to two teeth at the tip of the outer part. Male with hooks on third pereiopods. Areola wide or narrow, but never obliterated, about half as long as the anterior section of the carapace (incl. rostrum), or shorter. Chelæ elongated and subcylindrical.

2. Section: C. gracilis.

Sexual organs of male with one to two teeth at the tip of the outer part. Male with hooks on third pereiopods. Areola obliterated in the middle, considerably longer than half of the anterior section of the carapace. Chelæ short, broad, ovate.

3. Section: C. blandingi.

Sexual organs of male with one to three teeth at the tip of the outer part. Male with hooks on third and fourth pereiopods. Areola wide or narrow, rarely obliterated in the middle, shorter or longer. Chelæ generally elongated, narrow, and subcylindrical.

The most primitive sexual organs are found in species of the first section, where there is only one tooth at the end of the outer part. Similar sexual organs are found in the second (*C. advena*) and in the third section (*C. evermanni*): in the latter cases, however, I think we have to deal with parallelism, the single tooth in both cases being due possibly to reduction. Since these two species are very rare and poorly known, and since *C. evermanni* belongs to a group that offers other difficulties, further investigations are needed.

A closer examination may reveal the fact, that the sexual organs of the *digueti-group* are more sharply distinguished from those of *C. advena* and *evermanni*. Through the courtesy of Professor E. Bouvier of Paris, I have received two cotypes (male and female)

of his *C. digueti*, which show, on the one hand, that *C. carinatus* Fax. is a synonym of this species, and on the other hand, that the sexual organs have a rather peculiar shape. The figures of these organs, given by Faxon (*Pr. U. S. Mus.*, 20, 1898, pl. 63, f. 2 and 3) are absolutely correct, but the description (p. 648) is rather short and unsatisfactory. Faxon says: "Inner and outer parts ending in a small horny tooth, anterior margin furnished with a small tooth near the tip." Fig. 2 represents this organ of the right side, seen from the outside: the outer part ends bluntly, without a distinct tooth, while the inner part ends in a rather pointed tooth, outside of which is a sharp spine that is longer than the outer part. Faxon's Fig. 3 represents the identical part seen from the inside: only the two tips of the inner part are seen here, and the tip of the outer part is hidden behind the end of the inner; the inner part is flattened and hairy on the inside, and the "shoulder" ("small tooth near tip") is distinctly developed. My male specimen of *C. digueti* agrees in every detail with the figures of Faxon.

A very similar structure is seen in *C. cubensis* (Faxon, 1885, pl. 7, f. 5), only here the flattened face of the inside is dilated, and the shoulder is more prominent. In both cases, there are practically three tips to this appendage, *two* of which belong to the *inner* part.

The description of this organ in *C. mexicanus* (Faxon, *l. c.*, p. 50) agrees closely, but possibly the "small, procurved spine" attributed to the external part belongs to the internal, and then there would be complete agreement.

The double tip to the inner part, and the shoulder, which has a very peculiar position, possibly give to these three species a more isolated position within this subgenus, and might possibly justify the creation of a separate subgenus, which then should stand at the head of the genus. This would also agree well with the geographical distribution.

Aside from these more primitive species (*C. digueti*, *cubensis*, *mexicanus*), the first section contains two others (*C. simulans* and *gallinas*), which mark the transition to the third section, from which they differ only by the number of hooks of the male; the third section contains more advanced forms of the *simulans*-type. The second section is a peculiar side branch going off from the first section, which has acquired burrowing habits; this is known posi-

tively of *C. gracilis* and of *C. advena* (Hyeme vitam degit subterraneam. Aestate in fossis invenitur. Leconte).

The large number of species known in the third section makes a further division desirable, which is easily made according to the following characters:

1. Group: (spiculifer).

Outer part of sexual organs with two or three recurved teeth, without prominent angle (shoulder) on anterior margin. Rostrum with marginal teeth, acumen rather long. Areola wide, rarely narrow, distinctly shorter than half of the anterior section of the carapace.

2. Group: (blandingi).

Outer part of sexual organs with three (rarely two) recurved teeth, inner part with terminal spine directed obliquely outward. No shoulder on anterior margin. Rostrum with marginal teeth, acumem rather short. Areola narrow, generally distinctly longer than half of the anterior section of the carapace.

3. Group: (clarki).

Outer part of sexual organs with two compressed tubercles, inner part straight, directed forwards. Anterior margin with a distinct shoulder. Rostrum with marginal teeth, acumen rather short. Areola very narrow, often obliterated in the middle, about half as long as anterior section of carapace.

4. Group: (alleni).

Outer part of sexual organs with one or two teeth, often peculiarly formed (compressed and plate-like), inner part straight or oblique. No shoulder on anterior margin. Rostrum without marginal teeth (at least in the adult stage). Areola moderately wide, about half as long as anterior section of carapace.

There is no doubt, that the *spiculifer-group* is the most primitive of these, and that the others represent special modifications, each developed in a different direction.

The following key for the identification of the species of the subgenus *Cambarus* is submitted; it is claimed that this key represents — as far as is possible in a "key" — the natural affinities. If adult males of the first form are at hand, it should be possible, in every case, to correctly identify the species.

1. *Section of C. digueti* (see p. 98).

a_1 Sexual organs of male with only one terminal tooth on outer part, inner part with two tips; anterior margin with an angular projection (shoulder) near the tip (*digueti-group*).

b_1 Rostrum with marginal teeth.

c_1 Sexual organs of male with inner part not broadly dilated on inner side, curved forward at apex; shoulder small. Rostrum carinated above. Carapace with lateral spines. *C.* (*Cambarus*) *digueti* Bouv.

c_2 Sexual organs of male with inner part greatly dilated, forming a broad, flat, setose plate on inner side; shoulder strongly developed. Rostrum not carinated. Carapace without lateral spines. *C.* (*Cambarus*) *cubensis* Er.

b_2 Rostrum without marginal teeth, subplane above. Carapace without lateral teeth. Inner part of sexual organs flattened within, but not greatly dilated. *C.* (*Cambarus*) *mexicanus* Er.

a_2 Sexual organs of male with two terminal teeth on outer part, one of which is flat and disk-shaped, inner part with one terminal spine; without shoulder on anterior margin. Rostrum without marginal teeth (*simulans-group*).

b_1 Terminal teeth of sexual organs oblique, both of about the same length Acumen of rostrum longer. *C.* (*Cambarus*) *simulans* Fax.

b_2 Terminal teeth of sexual organs straight, one much longer than the other. Acumen of rostrum shorter. *C.* (*Cambarus*) *gallinas* Cock. and Port.

2. *Section of C. gracilis* (see p. 98).

a_1 Rostrum suddenly contracted into a short acumen. Sexual organs with two teeth at end of outer part. Terminal spine of inner part straight, longer than outer part.

b_1 Anterior margin of carapace forming a blunt suborbital angle. *C.* (*Cambarus*) *gracilis* Bund.

b_2 Anterior margin of carapace not forming a suborbital angle. *C.* (*Cambarus*) *hagenianus* Fax.

a_2 Rostrum triangular, margins not suddenly contracted to form an acumen. Sexual organs with only one compressed, triangular tooth at the end of outer part. Inner part straight, not longer than outer. *C.* (*Cambarus*) *advena* (Lec.).

3. *Section of C. blandingi* (see p. 98).

1. *Group of C. spiculifer* (see p. 100).

a_1 Areola wide. Chelæ rather broad. Two lateral spines on each side of the carapace.

b_1 Chelæ with large, remote tubercles. Margin of rostrum converging. Outer part of sexual organs with two terminal teeth. *C.* (*Cambarus*) *spiculifer* (Lec.).

b_2 Chelæ with small, crowded tubercles. Margins of rostrum subparallel· Outer part of sexual organs with three terminal teeth. *C.* (*Cambarus*) *versutus* Hag.

a_2 Areola wide or narrow. Chelæ generally narrower. One lateral spine on each side of the carapace.

b_1 Rostrum subplane above, ciliated. Areola wide. Outer part of sexual organs with two terminal teeth, the inner part with terminal spine directed outward. *C.* (*Cambarus*) *pubescens* Fax.

b_2 Rostrum concave above, smooth. Areola narrower.

c_1 Margins of rostrum subparallel. Outer part of sexual organs with two terminal teeth, the inner part straight.

C. (*Cambarus*) *angustatus* (Lec.).

c_2 Margins of rostrum convergent. Outer part of sexual organs with three terminal teeth, the inner part directed outward.

C. (*Cambarus*) *lecontei* Hag.

2. *Group of C. blandingi* (see p. 100).

a_1 Eyes rudimentary. Outer part of sexual organs with two terminal teeth.

C. (*Cambarus*) *acherontis* Loennb.

a_2 Eyes well developed. Outer part of sexual organs with three terminal teeth.

b_1 Sexual organs straight, terminal teeth well developed.

c_1 Sexual organs not excavated on outer side near distal end.

C. (*Cambarus*) *blandingi* (Harl.)

c_2 Sexual organs excavated on outer side near distal end.

C. (*Cambarus*) *hayi* Fax.

b_2 Sexual organs curved back distally, terminal teeth minute.

C. (*Cambarus*) *fallax* Hag.

3. *Group of C. clarki* (see p. 100).

a_1 Rostrum concave above, acumen slightly longer. Shoulder of sexual organs slightly developed. *C.* (*Cambarus*) *clarki* Gir.

a_2 Rostrum plane above, acumen shorter. Shoulder of sexual organs very prominent. *C.* (*Cambarus*) *troglodytes* (Lec.).

4. *Group of C. alleni* (see p. 100).

a_1 Outer part of sexual organs with one or two terminal teeth; inner part not longer than the outer. Hooks of fourth pereiopods of male not bituberculate.

b_1 Rostrum concave above. Outer part of sexual organs with one recurved terminal tooth; inner part with the terminal spine placed obliquely.

C. (*Cambarus*) *evermanni* Fax.

b_2 Rostrum plane above. Outer part of sexual organs with terminal part plate-like, covering the inner part, and with two very small teeth.

c_1 Chelæ bearded on inner margin. *C.* (*Cambarus*) *barbatus* Fax.

c_2 Chelæ not bearded on inner margin.

C. (*Cambarus*) *wiegmanni* Er. (?).

a_2 Outer part of sexual organs forming at apex a broad, flattened plate, whose anterior margin is furnished with hairs and one strong seta, the posterior margin of the plate produced anteriorly into a blunt process. Inner part produced into an erect spine, which is much longer than the outer part. Hooks of fourth pereiopods of male bituberculate.

C. (*Cambarus*) *alleni* Fax.

Note: The position of *C. wiegmanni* is very doubtful, since the male sexual organs are unknown. It has been placed with *C. barbatus* by Hagen and Faxon, but only the external resemblance to

this species speaks for its position here. The geographical distribution, however, is entirely opposed to it, and I very strongly suspect that it belongs somewhere else.

GEOGRAPHICAL DISTRIBUTION OF THE SUBGENUS CAMBARUS.

Taken as a whole, the subgenus *Cambarus* occupies a rather continuous area, with a possible interruption in northern Mexico: this gap, however, may be due only to the incompleteness of our knowledge. It covers Mexico, and a large part of the southern, central and eastern United States, but leaves unoccupied the mountainous region of the East; it is lacking in the larger part of Tennessee, in Kentucky, West Virginia, Pennsylvania, and northward. The largest number of species is found in the southeastern states: Mississippi, Alabama, Georgia, and this region represents at present the center of frequency of the subgenus. From here it extends, gradually declining, westward into Texas, northward up the Mississippi valley, becoming quite scarce north of the State of Missouri (only two species), and further it has populated the Atlantic coast plain as far north as New Jersey (only one species north of South Carolina).

Regarding the single sections, the distribution shows rather peculiar features. The *digueti-section* is characterized by a marked discontinuity: two species are found in Mexico, one in Cuba, and two in New Mexico, Texas and Kansas. Since I consider this section the most primitive of the genus, this discontinuity is highly interesting, and tends to confirm this view. And further, this peculiar distribution probably indicates the direction of the immigration into the United States. The most primitive forms (*C. digueti* and *mexicanus*) are still preserved in the original home of the genus, in Mexico, while two other, somewhat more advanced species (*C. simulans* and *gallinas*) occupy the higher plains lying to the east of the Rocky Mountains in the southwestern United States. These parts are largely formed by Cretaceous deposits, and represent the first land-connection between western and eastern North America after the Upper-Cretaceous separation. It is very significant, that just these parts contain the most primitive forms of the United States, and thus the distribution of the *digueti-section* clearly indicates this old condition prevailing at the end of the

Cretaceous and the beginning of the Tertiary time, and also gives a clue as to the direction of the migration: it did not go over the lowlands of Texas, which are geologically younger, but over the higher plains of the interior. (See Ortmann, 1902, pp. 282–285, p. 388.)

The *gracilis-section*, which is a specialized type, arising from the more primitive forms of the subgenus, forms in the distribution of the species *C. gracilis* a direct continuation of this southwestern range of the *digueti-section: C. gracilis* is found from eastern Kansas through Missouri, to Illinois, Iowa, and southern Wisconsin. This is in the same line of the migration marked by the distribution of the species of the *digueti-section*, and plainly its continuation in a northeastern direction. However, the two other species of the *gracilis-section*, *C. hagenianus* and *advena*, are entirely isolated, being found only far in the east, in the lowlands of Georgia and South Carolina. Here again we have discontinuity, indicating old age. I have no doubt, that these separated localities once were connected, namely from Kansas and northern Texas over Arkansas and across the Mississippi valley into Mississippi, and the northern, higher parts of Alabama and Georgia, including probably Tennessee.

Thus I think that the most primitive forms of *Cambarus* occupied, in the United States, first the Cretaceous plains of the southwest, necessarily reaching in very early times the Ozark Mountains, following the Ozark uplift into Illinois and beyond, and, on the other hand, crossing the present Mississippi valley, and reaching the southern end of the Appalachian system, and finally the sea coast in Georgia and South Carolina. Representatives of the primitive sections of the subgenus have now disappeared in the Appalachian region, and this is very likely due to the fact, that, as we shall see below, just in this region some other very vigorous groups developed, which apparently suppressed those earlier forms. In the southwestern extremity, where these new groups are rather scarce or entirely lacking, there was a chance for the old types to survive, and this may account for the presence of *C. simulans* and *gallinas* in this region, while *C. gracilis*, which is found right in the chief domain of the subgenus *Faxonius*, survived possibly on account of its different habits. For similar reasons *C. hagenianus* and *advena* may have survived at the extreme eastern seashore.

The *third* section of the subgenus *Cambarus* represents typically

the distribution of the whole subgenus, with the exception that it is not found in the extreme west and in Mexico. (I disregard *C. wiegmani*, since I do not believe that its position with this section is correct.)

Here again we have peculiar facts of distribution. The more primitive forms (*spiculifer-group*) are restricted to the states Georgia, Alabama, and northwestern Florida. Thus they come into close contact with the hypothetical old range of the more ancient types of the subgenus in the southern Appalachians, and I believe that they originated from an original stock of the *digueti-section*, that immigrated into the lowlands south of the mountains, which became dry land by degrees during Tertiary times. Here in these lowlands, chiefly in Alabama and Georgia, is the center of origin of the *blandingi-section*, which represents a secondary center for the subgenus. The more primitive forms (*spiculifer-group*) still stick to this center, while the more advanced forms have spread out from here as follows.

The *blandingi-group* invaded (*C. fallax*) northern Florida, and spread out northeastwardly along the Atlantic coast plain (*C. blandingi-typicus*), and also it migrated westward aud northward, up the Mississippi valley (*C. hayi* and *blandingi acutus*). The *clarki-group* extended chiefly westward from northern Florida far into Texas (*C. clarki*), and slightly eastward into South Carolina (*C. troglodytes*, in South Carolina and Georgia). Finally, the *alleni-group* occupied Florida: *C. alleni*, the most aberrant form, goes farthest south here (Caloosahatchee River, Lee Co.). (The other species, *C. evermanni* and *barbatus*, are known from scattered localities in Georgia, western Florida, and Mississippi, and their distribution needs further investigation; *C. wiegmanni* from Mexico possibly does not belong here.)

Thus the distribution of the subgenus *Cambarus* illustrates the early history of the immigration of the genus into the United States, and it also illustrates the later population of the southern parts of the United States during Tertiary times by forms of the *blandingi-section*. The latter prevail here, and hardly ever had any competitors, and thus the southern states are at the present time the center of the frequency of the whole subgenus. They are, however, the center of origin only for the *blandingi-section*, while the center of origin of the subgenus is to be sought in Mexico.

The more advanced forms of the subgenus *Cambarus* generally seem to prefer the ponds, lakes, and sluggish streams of the lowlands.

Subgenus: CAMBARELLUS (Type: *C. montezumæ*).

This subgenus corresponds to the fifth group of Faxon.

Faxon compares the male sexual organs with those of his fourth group (= *Faxonius*), but I rather think that they are more closely allied to those of his first and second group (= subgenus *Cambarus*). This latter relation, with the more primitive forms of the subgenus *Cambarus*, is confirmed by other characters: carapace and areola which are rather primitive, at least not very highly advanced; the rostrum has lateral teeth, which show a tendency to disappear; the chelæ are very simple, more or less elongated and subcylindrical, which is distinctly a primitive feature. The annulus ventralis of the female seems to be very remarkable in *C. montezumæ* (movable, fixed only at the posterior end), and also in *C. shufeldti* (a transverse curved ridge, the hind side of the ridge concave).

The three species of the subgenus may be distinguished as follows:

a_1 Sexual organs of male with straight terminal teeth. Carapace with lateral spines. Rostrum with distinct marginal spines.
C. (*Cambarellus*) *shufeldti* Fax.

a_2 Sexual organs of male with curved terminal teeth. Carapace without lateral spines. Rostrum with or without marginal spines.

- b_1 Carapace slender and subcylindrical. Rostrum longer and narrower, with sharp marginal spines, and long, spiniform acumen.
C. (*Cambarellus*) *chapalanus* Fax.
- b_2 Carapace ovate. Rostrum shorter and wider, with or without marginal spines, in the first case, the acumen is much shorter.
C. (*Cambarellus*) *montezumæ* Sauss.

C. shufeldti is apparently more primitive than the other two species. I have no doubt that *Cambarellus* took its origin from the most primitive species of the subgenus *Cambarus* (*digueti-group*), but developed in a peculiar direction, which is chiefly characterized by the male sexual organs, and by the presence of hooks on the second pereiopods, a condition that is found nowhere else in the genus.

The *distribution* of this subgenus also suggests its antiquity, for it is characterized by a strong discontinuity, *C. shufeldti* being found in Louisiana, the other two species in Mexico. This geographical discontinuity is accompanied by morphological discontinuity, the former species differing very strongly from the two latter. While

C. chapalanus and *montezumæ* still remain in the original home of the genus, although they have changed a good deal, *C. shufeldti* seems to be an early emigrant, which, however, has not much changed. Further investigations in this subgenus are much needed.

Subgenus: FAXONIUS (Type: *C. limosus*).[1]

This subgenus corresponds to Faxon's fourth group, with the addition of *C. pellucidus*. As regards the latter species, which Faxon places with his first group, apparently chiefly on account of the presence of hooks on the third and fourth pereiopods in the male, it is easy to see that the sexual organs do not agree with the *blandingi-type*. Faxon himself says (1885, p. 42), that they are very simple, and generally admits that this species unites characters of different groups. Looking at the figures of the sexual organs given by Hagen (Ill. Cat. Mus. Harvard, 3, 1870, pl. 1, f. 68–71), and Hay (*P. U. S. Mus.*, 16, 1893, pl. 45, f. 11–14), I fail to see any similarity to any of the species of the subgenus *Cambarus*, but their shape approaches rather closely that of some species of Faxon's fourth group, namely: *C. limosus*, *indianansis* and *sloanei*. Indeed, in *C. pellucidus* this organ is different from any one of these, but it agrees with them in the more or less straight and simple form, with the outer and inner parts separated at the tips for a short distance; there is also no trace of a terminal truncation. The rostrum and the chelæ are rather primitive in *C. pellucidus*, while carapace and areola are peculiar, which is possibly a character due to the subterranean life (see Faxon).

If we place *C. pellucidus* with the species of the fourth group named above, it loses its isolated position also with reference to the geographical distribution: it is found in a region (Kentucky and southern Indiana), where at least two of the above species are also found: *C. indianansis* and *sloanei*.

I think, that *C. pellucidus* is a rather primitive form, connecting the subgenus *Faxonius* with the more primitive forms of *Cambarus*

[1] *Astacus limosus* of Rafinesque has been considered by all authors (Girard, Hagen, Faxon) as very probably identical with *A. affinis* of Say. Although Rafinesque's description is very poor, the locality given ("muddy banks of the Delaware near Philadelphia") renders it absolutely certain that *C. affinis* was intended. There is no other species on the banks of the Delaware but this, and it is so abundant there, that it even attracts the attention of the casual observer. Thus I do not see why the older name of Rafinesque should not be restored.

(*digueti-group*), and that the development of an additional pair of hooks on the fourth pereiopods is a parallelism to the similar tendency in the more highly advanced forms of the subgenus *Cambarus* (*blandingi group*) : to the latter, *C. pellucidus* has no direct relation at all.

With regard to all the rest of the species of this subgenus, I agree with Faxon in thinking them to form a natural, genetically connected group. Nevertheless there is much diversity within this subgenus, and is chiefly indicated by the shape of the male sexual organs. Faxon did not use the latter in arranging the species of his fourth group, and thus his key (1885, p. 86) is, as he admits himself, artificial to a degree. But I shall show here, that according to the sexual organs we can divide the subgenus in groups, which seem to be quite natural.

1. *Section : C. limosus.*

Sexual organs short, rather thick up to near the tips, reaching to the base of the third pair of pereiopods. Tips split for a short distance, each tapering to a point. Hooks on third, or on third and fourth pereiopods.

This is the most primitive section of the subgenus, and it is also in other characters quite indifferent, and not highly specialized; and further, it appears a little heterogeneous. The rostrum is quite uniform in shape, generally with marginal spines (except in certain varieties of *C. pellucidus*), with a rather long or a moderate acumen. The areola is wide and of medium length (except *C. pellucidus*); the chelæ are comparatively narrow and without remarkable features (except in *C. harrisoni*).

The annulus of the female shows the tendency to develop tubercles upon its face; these tubercles have a more or less central position (*limosus, indianensis*), or a posterior (*sloanei*), or have the shape of a transverse ridge (*harrisoni*), or form a "median keel" (*pellucidus*).

2. *Section : C. propinquus.*

Sexual organs shorter or longer, not thick, deeply split at the tips, tips slender, more or less straight, sometimes the outer one slightly curved, but never both tips curved in the same direction. Always only third pereiopods with hooks (barring freaks).

The other characters are very uniform in this section. The rostrum possesses with one exception (*C. medius*), marginal spines,

and a rather long or moderate acumen. The carapace is of normal shape, oval and depressed; the areola uniformly rather wide, and there is no tendency to become narrow. There are, however, some differences in length: generally, the areola is about half as long as the anterior section of the carapace (incl. rostrum); but in certain species (*erichsoni* and *forceps*) it is slightly, and in one species (*spinosus*) decidedly shorter, and in two others (*rusticus* and *medius*) it is decidedly longer. The chelæ in this section are also rather uniform, but not very primitive: they are more or less broad and ovate. The fingers (in old males) generally are gaping at the base, and in contact distally, and the movable finger possesses a peculiar S-shaped curve. The immovable finger is generally not bearded at the base (a slight indication of a beard is seen in: *C. propinquus, obscurus, neglectus*). In *C. forceps*, the fingers are unusually and widely gaping, up to the tips. In *C. medius* the chelæ are unusually broadly ovate, and the movable finger has no S-curve.

The annulus of the female is flat, with a median depression and raised margins. Very often the anterior margin is elevated into tubercles, and in *C. hylas* the posterior margin is very prominent, which is rather unusual in this section, and ought to be confirmed by additional investigations.

This section contains ten species, which may be divided into two groups.

1. *Group: (propinquus).*

Tips of sexual organs comparatively short, reaching only to the third rarely (in erichsonianus) to the second pereiopods, without or with (obscurus) a shoulder on the anterior margin. Outer tip regularly tapering from base to end.

2. *Group: (rusticus).*

Tips of sexual organs long, reaching rarely only to the second, generally to the first pereiopods, mostly with a shoulder on the anterior margin. Outer tip not regularly tapering, but thin (setiform) from base to end.

C. erichsonianus forms a transition between the two groups: the sexual organs are rather long, but they lack a shoulder, and in shape they resemble those of *C. propinquus.*

3. *Section: C. virilis.*

Sexual organs generally quite long (rarely rather stout), reaching about to the second pereiopods, deeply split at the tips, tips slender

(rarely shorter) and more or less strongly curved backward, both in the same direction. Always only the third pereiopods with hooks (barring freaks).

The shape of the sexual organs is quite uniform in this section, and they do not vary much in the different species, with one exception: *C. difficilis.* Here they are remarkably short and stout, reaching only to the third pereiopods. But we cannot separate this species on this account from the section, since in other characters it is closely allied to *C. palmeri.*

This section closely approaches the *propinquus* type, especially that represented by *C. rusticus,* in fact, the curvature of the tips of the sexual organs is the only important differential character. Besides, however, there is in no case a shoulder developed here, which is so frequently seen in the *propinquus-section.*

In other characters this section is more variable than the *propinquus-section,* and this is most evident in the width and length of the areola. The chelæ are built according to the type of the *propinquus-section,* but a remarkable character is the presence of a dense tuft of hairs (*beard*) at the base of the immovable finger. This beard is absent in *C. compressus* only. In two species, *C. alabamensis* and *compressus,* the chelæ are very broad, and exceptionally smooth.

The annulus of the female is depressed in the middle, with raised margins, similar to that of some species of the *propinquus-section* (*virilis, longidigitus*). In other cases it is elevated posteriorly, and the anterior part is depressed; it is never elevated anteriorly, as is generally the case in the *propinquus-section.* (In some species, *alabamensis* and *mississippiensis,* the description of the annulus is inadequate).

The eleven species of this section are easily arranged into three groups according to the areola.

1. *Group*: (*alabamensis*).
   Areola wide and short.
2. *Group*: (*virilis*).
   Areola narrow, of medium length.
3. *Group*: (*palmeri*).
   Areola obliterated in the middle, of medium length.
4. *Section*: *C. lancifer.*
   Sexual organs very peculiar; short, and with slightly curved tips, the outer tip remarkably compressed.

This section is formed to receive an isolated species, the position of which seems quite uncertain. There is a remote resemblance of the sexual organs to those of *C. difficilis* of the third section of this subgenus, and in other characters there are resemblances to *C. mississippiensis*, namely in the lack of marginal spines of the rostrum, and in the obliteration of the areola. The annulus of the female agrees with *C. palmeri* in being depressed in front, and prominent and tuberculated behind: but a similar shape is found in the subgenus *Bartonius*. On the other hand, also the male sexual organs can be compared with *Bartonius*, although they are by no means identical with the very uniform type seen in the latter subgenus. The chelæ, according to the description, are very peculiar, namely long and subcylindrical, the palm with subparallel margins: this is entirely unlike anything that is seen in the *virilis-section* of the present subgenus, and rather stamps this species a primitive one. Then, again, this species presents in the elongate rostrum and antennal scale very unusual features.

Thus it is hard to form a positive opinion about its position. I should not hesitate to place it with the *palmeri-group* of the *virilis-section*, if it was not for the primitive character of the chelæ. According to the latter, and possibly also according to the sexual organs, we might place it at the beginning of the subgenus, as a peculiarly developed primitive form, but it also may be the most highly specialized form of the subgenus. The distribution (Mississippi and northeastern Arkansas) would fit either assumption.

KEY TO THE SPECIES OF THE SUBGENUS FAXONIUS.

1. *Section of C. limosus* (see p. 108).

a_1 Generally third and fourth pereiopods with hooks in the male. Carapace subcylindrical. Areola wide and long. Chelæ subcylindrical. Eyes rudimentary. *C.* (*Faxonius*) *pellucidus* (Tellk.).

a_2 Only third pereiopods with hooks in the male. Carapace ovate, depressed. Areola rather wide, of medium length (about half as long as anterior section of carapace). Chelæ not subcylindrical, compressed, and more or less ovate. Eyes well developed.

b_1 Sexual organs thick, swollen in the middle, tips short and stout, both slightly curved in the same direction. *C.* (*Faxonius*) *harrisoni* Fax.

b_2 Sexual organs short, thick, but not swollen, straight. Tips divergent.

c_1 Sides of carapace with one spine behind the cervical groove.

d_1 Sexual organs with tips not crossed, the outer directed outward, the inner inward. *C.* (*Faxonius*) *sloanei* Bund.

d_2 Sexual organs with tips crossed, the outer inside directed ~~in~~ out ward, the inner outside ~~outward~~. dir. inv. a. a. C. (*Faxonius*) *indianensis* Hay.

c_2 Sides of carapace spinose, several spines behind cervical groove, and spines on the hepatical region. Tips of sexual organs crossed. C. (*Faxonius*) *limosus* (Raf.).

2. *Section of C. propinquus* (see p. 108).

1. *Group of C. propinquus* (see p. 109).

a_1 Sexual organs reaching to the third pereiopods, with or without shoulder.

b_1 Rostrum with or without median keel. Sexual organs without shoulder on anterior margin. C. (*Faxonius*) *propinquus* Gir.

b_2 Rostrum without median keel. Sexual organs with shoulder on anterior margin. C. (*Faxonius*) *obscurus* Hag.

a_2 Sexual organs reaching to the second pereiopods, without shoulder. C. (*Faxonius*) *erichsonianus* Fax.

2. *Group of C. rusticus* (see p. 109).

a_1 Rostrum with marginal spines. Carapace with a lateral spine.

b_1 Margins of rostrum concave. Sexual organs reaching to the second pereiopods

c_1 Tip and marginal spines of rostrum bent upward. Fingers of chela gaping only at base. C. (*Faxonius*) *rusticus* Gir.

c_2 Tip and marginal spines of rostrum not bent upward. Fingers of chela gaping to the tips. C. (*Faxonius*) *forceps* Fax.

b_2 Margins of rostrum straight, generally subparallel. Sexual organs reaching to the first pereiopods.

c_1 Rostrum with distinct median keel. Sexual organs without shoulder. C. (*Faxonius*) *neglectus* Fax.

c_2 Rostrum without median keel. Sexual organs with more or less distinct shoulder.

d_1 Areola shorter than half of the anterior section of carapace. C. (*Faxonius*) *spinosus* Bund.

d_2 Areola half as long as the anterior section of carapace.

e_1 Margins of rostrum almost parallel, C. (*Faxonius*) *putnami* Fax.

e_2 Margins of rostrum distinctly convergent. C. (*Faxonius*) *hylas* Fax.

a_2 Rostrum without marginal spines. Carapace without lateral spines. C. (*Faxonius*) *medius* Fax.

3. *Section of C. virilis* (see p. 109).

1. *Group of C. alabamensis* (see p. 110).

a_1 Areola very short. Carapace not compressed. C. (*Faxonius*) *alabamensis* Fax.

a_2 Areola a little longer. Carapace compressed. C. (*Faxonius*) *compressus* Fax.

2. *Group of C. virilis* (see p. 110).

a_1 Margins of rostrum concave, acumen moderately long, together with marginal spines bent upward. G. (*Faxonius*) *meeki* Fax.

a_2 Margins of rostrum straight, parallel or convergent. Marginal spines and acumen not bent upward.

b_1 Acumen of rostrum long, marginal spines sharp, margins parallel. Fingers of chela long. *C.* (*Faxonius*) *longidigitus* Fax.

b_2 Acumen of rostrum short, marginal spines small or absent, margins more or less convergent.

c_1 Acumen of rostrum not considerably shorter than width of rostrum at base; marginal spines small, but present; margins slightly convergent; upper surface slightly concave. Fingers of chelæ not remarkably long and not emarginate at base.

d_1 Sexual organs longer, slightly curved.
C. (*Faxonius*) *virilis* Hag.

d_2 Sexual organs shorter, more strongly curved.

e_1 Immovable finger bearded at base, chela for the rest without hairs. *C.* (*Faxonius*) *nais* Fax.

e_2 Immovable finger bearded at base, chela pilose.
C. (*Faxonius*) *pilosus* Hay.

c_2 Acumen of rostrum considerably shorter than width of rostrum at base; marginal spines generally wanting (rarely present and small); upper surface deeply concave; margins strongly convergent. Movable finger of chela with a deep emargination at base of inner margin.
C. (*Faxonius*) *immunis* Hag.

3. *Group of C. palmeri* (see p. 110).

a_1 Rostrum with marginal spines.

b_1 Sexual organs long. *C.* (*Faxonius*) *palmeri* Fax.

b_2 Sexual organs remarkably short. *C.* (*Faxonius*) *difficilis* Fax.

a_2 Rostrum without marginal spines. *C.* (*Faxonius*) *mississippiensis* Fax.

4. *Section of C. lancifer* (see p. 110).

Rostrum very long, without marginal spines. Antennal scale very long. Areola obliterated in the middle. Chelæ long, subcylindrical.
C. (*Faxonius*) *lancifer* Hag.

GEOGRAPHICAL DISTRIBUTION OF THE SUBGENUS FAXONIUS.

The area occupied by this subgenus is almost entirely continuous; it extends over all of the central parts of the United States, from northern Texas to Lake Winnipeg in Canada, and from Kansas to the Appalachian Mountains. To the south, it hardly encroaches upon the domain of the subgenus *Cambarus*, being found only in the northern parts of Alabama and Georgia. To the North, it reaches the Great Lakes, and follows down the St. Lawrence valley. Eastward, the Allegheny Mountains apparently form a boundary, but at two places it has crossed these mountains, namely in the north, where *C. limosus* is found in the lowlands and rivers of

Virginia, Maryland, Pennsylvania and New Jersey; and in the south, where *C. spinosus* and *erichsonianus* cross over from the Tennessee River drainage into that of the gulf and the Atlantic Ocean in Alabama, Georgia, South and North Carolina. These latter cases are continuous, the same species being found in both drainages, while in the former case discontinuity is implied, *C. limosus* being cut off and isolated from the rest of the range of the subgenus.

Generally speaking, this subgenus seems to belong to the great rivers of the interior basin, its center lying about in the region where the rivers Missouri, Mississippi, and Ohio come together, that is to say, in the states of Mississippi, Kentucky, southern Illinois, and southern Indiana. From this center it spreads out in the directions of these rivers and tributaries, chiefly toward the North and Northeast. However, the area remained not restricted to the Mississippi drainage, but crossed the divides into other systems in the following cases: From the Tennessee River two species (*spinosus, erichsonianus*) have crossed over into the Gulf and Atlantic drainages, and from the upper Ohio drainage another species (*limosus*) has crossed over into the Chesapeake and Delaware Bay drainage. Another species (*mississippiensis*) is found in the Gulf drainage (outside of that of the Mississippi River) in the state of Mississippi. In the North the area largely extends into the drainages of the great lakes, and even into that of Hudson Bay (through the Red River of the North and Winnipeg Lake).

Studying the distribution of the single sections, the following is to be remarked. The most primitive *section* (that of *C. limosus*) is marked by discontinuity: *C. limosus* being found on the Atlantic coast plain, *C. pellucidus, indianensis, sloanei* in Kentucky and southern Indiana, *C. harrisoni* in Missouri. This discontinuity, chiefly the isolation of *C. limosus*, is accompanied by morphological isolation, the latter species possessing in its spinosity a character, that only recurs in the allied, but otherwise peculiar species, *C. pellucidus*. This latter species, as well as *C. sloanei, indianensis* and *harrisoni*, undoubtedly are the last remnants of the primitive stock of the subgenus in its original home, *i. e.*, in the central basin formed by the three great rivers. Thus the geographical distribution of the *limosus-section* confirms the character of antiquity: most of the species remain in the original

home, while *C. limosus* apparently is an early emigrant that has crossed over into the Atlantic drainage, and has been entirely cut off from the connection with the original stock. At present, I am not prepared to say which was the way by which *C. limosus* reached its present habitat.

The *section of C. propinquus* contains quite a number of species: studying their distribution, we see that the distributional areas of the two groups into which this section is divided correspond to the main ranges of two species, while the other species seem to be rather local forms of these. The typical form of the *propinquus-group*, *C. propinquus*, occupies a continuous range that belongs in part to the Mississippi drainage (Iowa, Illinois, Minnesota), in another part to the Ohio drainage (in Indiana), and for the rest to the Lakes and St. Lawrence drainage (in Michigan, Ohio, Pennsylvania, New York and Canada). Compared with *C. rusticus*, this range is more northern and northeastern, and it is remarkable, that there is hardly a locality known for the typical *C. propinquus*, that lies south of the Terminal Moraine of the Wisconsin ice sheet. *C. obscurus* is found at the eastern edge of the range of *C. propinquus*, namely in the upper Ohio drainage in western Pennsylvania and western New York (See Ortmann, *Ann. Carnegie Mus.*, v. 3, 1905, p. 387–406), and seems to be the representative form of *C. propinquus*, in this region.

C. rusticus, the typical species of the *other group* of this section, has a wide range over the central basin, from Ohio, Indiana, and Kentucky to Iowa, Missouri, and Tennessee. With reference to *C. propinquus* it is more southern and western, although it extends, in Ohio, far northward, and is found in the lake drainage in Michigan and Wisconsin. (The investigation of the distribution of these two species, *rusticus* and *propinquus*, in Ohio, Indiana, Illinois, Michigan, and Wisconsin will certainly be very interesting.) Associated with *C. rusticus* in the same group are six other species: all of these are rather local, and all are found at or near the edge of the range of *C. rusticus*. *C. forceps*, *spinosus*, and *putnami* are found at the southeastern edge, namely in the Cumberland and Tennessee river drainages in Kentucky, Tennessee, and northern Alabama. One of these species (*spinosus*) has crossed over into the Gulf and Atlantic drainages in northern Georgia, South and North Carolina. (This is an additional case throwing light upon

the changes of the drainage systems in the southern Appalachians, see: Simpson, *Science*, 12, 1890, p. 133, and chiefly Adams, *Americ. Natural.*, 35, 1901, p. 844 ff.; where on p. 849 three species of Cambarus are mentioned (*C. spinosus, extraneus*, and *erichsonianus*) that belong into this category). The species *C. neglectus, hylas*, and *medius* belong to the southwestern and western edge of the range of *rusticus*, and are found in Missouri, Arkansas, Texas, Kansas, and Iowa. Thus it is evident, that the six species morphologically allied with *C. rusticus* in the same group, express this relation also in their distribution, being apparently locally modified forms of the *rusticus*-type, and being naturally found just where we ought to expect them, namely at the edge of the range of this *rusticus*-type.

C. erichsonianus seems to be abnormal: morphologically we have placed it with *C. propinquus*, but its range is far remote from it in eastern Tennessee and central Alabama (in both the Tennessee and Alabama river drainages). But, as we have seen above, its position is a little uncertain, it resembling *C. rusticus* and its allies to a degree, and the distribution suggests the same: it clearly agrees better in this respect with *C. forceps* and *spinosus*, and it would thus become another local form of the *rusticus*-type. Further investigations on this question should be made.

The *third section*, that of *C. virilis*, has been divided into three groups. The *virilis-group* agrees somewhat with the *rusticus-group* in its range, belonging to the central basin, only being a little more western, and considerably more northern: it is hardly found in the drainage of the Ohio, but it is very abundant in that of the Mississippi and Missouri, and crosses over not only into the lake drainage, but also into that of Hudson Bay (Winnipeg Lake). The typical species of the group (*virilis*) occupies almost all of this range, while four other species associated with it (*meeki, longidigitus, nais, pilosus*) apparently are local forms of it, being found at or near the southwestern extremity of the range of *C. virilis* in Arkansas and Kansas. *C. immunis* is a peculiar type of the *virilis-group*, and its range coincides with the southern part of the range of *C. virilis* (Kansas, Missouri, Iowa, Illinois, Indiana, Ohio): this is interesting in so far as this occupation of the same territory by two closely allied species is rendered possible as it seems in this case, by the different habits: as far as we know, *C.*

immunis inhabits the (often temporary) shallow, stagnant ponds and roadside ditches of the western prairies, and is a burrower, while *C. virilis* prefers rocky places in running streams. (See Harris, *Americ. Natural.*, 35, 1901, f. 187 ff., and *Kansas Univ. Quart.*, 9, 1900, pp. 268 and 270).

Of the other two groups of the third section, that of *C. alabamensis* contains only two species, which are very local, being found only in northern Alabama. Both are rather primitive, and apparently are the last remnants in the Tennessee drainage of a once more widely distributed stock. The *difficilis-group* seems to represent a southern extension of the subgenus *Faxonius*: the species are found in western Tennessee, Missouri, Arkansas, Indian Territory, northeastern Texas and Mississippi, all in the drainage of the lower Mississippi (below Cairo), only *C. mississippiensis* belongs to the Tombigbee river drainage.

C. lancifer would agree in its range (Mississippi and Arkansas) with this latter group.

The species of this subgenus, generally, are river-species, and prefer the large rivers of the great central basin. Some species have become lake-forms (*C. propinquus*, for instance), and others ascend the rivers into the smaller streams (chiefly so in the Tennessee and upper Ohio drainages), but they rarely inhabit true mountain streams.

Further investigation of the distribution of this subgenus should pay particular attention to the ways by which several species have crossed the divides of the Hudson Bay, Great Lakes, and Atlantic coast plain drainage systems. It is very likely that wandering of the divides has played here an important part.

Subgenus: BARTONIUS (Type: *C. bartoni*).

This subgenus, which corresponds to the third group of Faxon, is a very natural one, and, in my opinion, contains the most modern and most highly specialized forms in those that have acquired burrowing habits (*diogenes-section*). There are, however, other species, which are rather primitive, as indicated by certain characters.

The length of the areola, in this subgenus, is rather variable: in the *extraneus-section* it is shortest, about half as long as the anterior section of the carapace, and it is even shorter than that in *C. acuminatus*. In all other species it is considerably longer. The an-

nulus of the female is, corresponding to the uniformity of the male organs, also very uniform, and is characterized by its posterior elevation. Aside from the length and width of the areola, the shape of the chelæ, the presence or absence of marginal spines of the rostrum, and the shape of the carapace serve to distinguish the more primitive forms from the more highly developed, and furnish a division of the subgenus into sections as follows:

1. *Section: C. hamulatus.*

Carapace subcylindrical. Rostrum with or without marginal spines. Chelæ long, subcylindrical. Areola rather long. Eyes rudimentary.

Only two species, *C. hamulatus* and *setosus*, belong here, both blind cave-forms. They do not seem to be closely related to one another, since they differ in very important characters. The subcylindrical shape of the chelæ, however, indicates, that both are rather primitive, and have become separated from the primitive stock of this subgenus very early, and probably independently. The shape of the carapace, the long areola, and the rudimentary eyes are very likely due to parallel development, brought about by the similar conditions under which these species are found. (See Faxon, *Pr. U. S. Mus.*, v. 12, 1890, p. 628).

2. *Section: C. extraneus.*

Carapace more or less ovate, depressed, with lateral spines behind cervical groove. Chelæ not very elongated, depressed, and rather broad, but a little more elongated than in the following sections. Areola more or less wide, of medium length, about half as long as anterior section of carapace, sometimes slightly shorter, rarely, in C. cornutus, the areola is rather long. Eyes well developed.

Two of the species belonging here (*C. extraneus* and *jordani*) are typical, and are unquestionably the most primitive forms of the subgenus, as is shown by the shape of the carapace, the rostrum, and chelæ, at least as compared with the following sections. The third species, *C. cornutus*, stands by itself, and is a rather aberrant form, peculiar on account of its antennæ, which have a large, compressed flagellum, ciliated on inner margin. Also the spines of the rostrum (upturned) are peculiar. In the long areola, it is rather advanced. It seems to be a peculiar local form, developed out of the primitive stock now represented by *C. extraneus* and *jordani*, and we may safely leave it with this section, since the only alternative would be to create for it a separate section.

3. *Section : C. bartoni.*

Carapace ovate, depressed, with or mostly without lateral spines. Rostrum without marginal spines. Chelæ comparatively short and broad, depressed, ovate. Areola wide or narrow, generally distinctly longer than half of the anterior section of the carapace, only in one case (C. acuminatus) slightly shorter than half of the anterior section. Eyes well developed.

The four species belonging here are all closely allied to one another. Their chief differences are furnished by the shape of the rostrum, width and length of areola, and shape of chelæ: but all are built according to the same plan.

4. *Section ; C. diogenes.*

Carapace ovate, compressed, without lateral spines. Rostrum without marginal spines. Chelæ short and broad, depressed, ovate. Areola very narrow or obliterated in the middle, always distinctly longer than half of the anterior section of the carapace. Eyes well developed.

The five species belonging into this section also form a very natural group. They are connected with the *bartoni-section* through *C. latimanus* (chiefly its var. *striatus* Hay). The peculiar, compressed shape of the carapace (and possibly other characters, as shape of rostrum, narrow areola, shape of chelæ) seems to be closely connected with the habits: all these species (it has *not* been reported for *C. uhleri* but it is likely also the case with this one) are burrowing species and so-called chimney-builders. This habit begins to appear in the *bartoni-section : C. bartoni* often, but not always, makes burrows and chimneys, apparently forced to do so, when the water supply of the small mountain streams, in which it lives, begins to run short in dry seasons. With the species of this group, this habit becomes firmly established, and they never live without making burrows, having abandoned the streams and brooks, and taken to swampy and springy places, generally to the groundwater, where it is found at a short distance below the surface.

The species of this section are distinguishable by the width of the areola, shape of rostrum, shape of the chelæ, and in some cases by peculiar colors. I believe that it is the most highly specialized group of the whole genus, as is indicated partly by the burrowing habits, no doubt an extreme adaptation, and, in one species (*C. uhleri*), by the adaptation to brackish and salt-water, which is found in no other case in the genus.

KEY TO THE SPECIES OF THE SUBGENUS BARTONIUS.

1. *Section of C. hamulatus* (see p. 118).

a_1 Rostrum with marginal spines. Areola wide.
C. (*Bartonius*) *hamulatus* (Cope and Pack.).

a_2 Rostrum without marginal spines (rarely with spines in the young). Areola narrow. C. (*Bartonius*) *setosus* Fax.

2. *Section of C. extraneus* (see p. 118).

a_1 Antennæ with normal flagellum.

b_1 Rostrum concave above. Areola rather wide.
C. (*Bartonius*) *extraneus* Hag.

b_2 Rostrum flat above. Areola narrower. C. (*Bartonius*) *jordani* Fax.

a_2 Antennæ with very long, compressed flagellum, which is ciliated on the inner side. C. (*Bartonius*) *cornutus* Fax.

3. *Section of C. bartoni* (see p. 119).

a_1 Rostrum long, tapering from base to tip. Areola very wide and short, a little shorter than half of the anterior section of carapace. Carapace with lateral spines. C. (*Bartonius*) *acuminatus* Fax.

a_2 Rostrum shorter, suddenly contracted to a short acumen. Areola moderately wide or narrow, distinctly longer than half of the anterior section of carapace. Carapace with or without lateral spines.

b_1 Areola rather wide. Chelæ smooth, punctate, inner margin of palm with one or two rows of tubercles.

c_1 Fingers of chelæ broad, slightly gaping at base, not bearded.
C. (*Bartonius*) *bartoni* (F.).

c_2 Fingers of chelæ subcylindrical, widely gaping at base, the outer one bearded at base. C. (*Bartonius*) *longulus* Gir.

b_2 Areola narrower. Chelæ rough or tuberculated.
C. (*Bartonius*) *latimanus* (Lec.).

4. *Section of C. diogenes* (see p. 119).

a_1 Areola very narrow, but not obliterated. Color very striking.

b_1 Rostrum broad. Outer margin of hand serrate. Color red.
C. (*Bartonius*) *carolinus* Er.

b_2 Rostrum narrower. Outer margin of hand not serrate. Color blue.
C. (*Bartonius*) *monongalensis* Ortm.

a_2 Areola obliterated in the middle. Color dull, greenish or brownish.

b_1 Rostrum concave above.

c_1 Fingers of chelæ not remarkably flattened, the inner one without distinct excision at base, the outer one not bearded,
C. (*Bartonius*) *diogenes* Gir.

c_2 Fingers of chelæ flattened, the inner one with distinct excision at base, the outer one bearded. C. (*Bartonius*) *argillicola* Fax.

b_2 Rostrum flat above. C. (*Bartonius*) *uhleri* Fax.

GEOGRAPHICAL DISTRIBUTION OF THE SUBGENUS BARTONIUS.

This subgenus is characteristic for the mountainous regions of the east of the United States, that is to say, for the Appalachian mountains, but the more highly developed, burrowing species have in part descended from the mountains, and spread largely over the central portions of this country. The greatest number of species is found in the southern extremity of the Appalachian system, and there is no question that we have to regard this as the center of origin of the subgenus.

The two cave forms of the *first section* are widely separated from each other. This indicates, on the one hand, that they are not very closely allied, and, on the other hand, the discontinuity thus displayed again indicates antiquity. The one, *C. hamulatus*, is found in a cave in eastern Tennessee, that is to say, right in the center of origin of the subgenus, while the other one, *C. setosus*, comes from a cave in Jasper Co., Missouri (in the Ozark region). This is very remarkable, and very likely indicates, that the center of origin of the subgenus possibly includes the Ozark Mountains, west of the Mississippi: this is further suggested by the reported presence of *C. carolinus* in the northeastern part of Indian Territory, not far from the locality of *C. setosus* (see below). Consequently, we are to regard *C. setosus* as the last remnant of the primitive forms of the subgenus surviving in the western extremity of the original home.

We have regarded, morphologically, the *second section* of the subgenus as the most primitive group of it: this view is supported by the geographical distribution. *C. extraneus* is known from northern Alabama, northern Georgia, Tennessee, and Kentucky (see below, p. 134); *C. jordani* is found in northern Georgia; and *C. cornutus* in Kentucky (locally, only in Edmonson Co.). Thus all the localities are in or near the old center of origin of the subgenus. The presence of *C. extraneus* in the Cumberland and Tennessee river drainages, as well as in the Alabama river drainage indicates an old drainage feature, namely the Appalachian river (see above, p. 116).

The *third section* presents very interesting conditions, such as we have noticed in several groups of the subgenus *Faxonius*. Here we have apparently one widely distributed, typical form, *C. bartoni*: this is found all along the Appalachian mountains and extends very

far to the northeast. This species has followed, in its dispersal, chiefly the direction of the strike of this mountain chain, and reaches now from Tennessee to Maine and New Brunswick. Eastward, it hardly decends to the Atlantic plain, at any rate it does not spread over it, and westward it goes as far as Indiana, always preferring smaller streams in mountainous or hilly regions.

C. bartoni possesses several marked varieties, chiefly at the southern and southwestern extremity of its range, in Kentucky, Tennessee and northern Georgia; one variety (*robustus*) seems to follow the northwestern edge of the range of the main species, from Ohio through northwestern Pennsylvania to western New York (and in Canada). This variety has also been reported from Maryland and Virginia, but I doubt that this is actually the same thing (see below, p. 135).

Besides, there are three other species in this section, which are closely allied to *C. bartoni*. One of them, *C. acuminatus*, is found in North and South Carolina, at the southeastern edge of the range of *C. bartoni*; the second, *C. latimanus*, fringes the southern and southwestern extremity of the area of *C. bartoni* in South Carolina, northern Georgia, northern Alabama, and central Tennessee; and the third, *C. longulus*, is apparently a form belonging to the high mountains, being found in the middle of the southern part of the main range of *C. bartoni* along the highest mountain chains of North Carolina, Tennessee, Virginia, and West Virginia. Thus it is beyond question, that we can regard these three species as local forms of *C. bartoni*, the one belonging to the high mountains, another being its southeastern, the third its southern and southwestern representative.

While the *first* and *second sections* characterize the earlier stage of the distribution of the subgenus, the *third section* expresses its advance and dispersal over the eastern mountain system of the United States.

Finally, the *fourth section* (of *C. diogenes*) offers remarkable conditions. Two of the species, belonging here (*C. carolinus* and *monongalensis*) are evidently a little more primitive than the rest. *C. carolinus* seems to possess a wide range within the Appalachian system. It is a true mountain form, and is found from northern South Carolina to southern Pennsylvania, thus representing the same direction of migration as *C. bartoni*, from southwest to north-

east, parallel to the strike of the mountains. This species, however, has also been reported from Indian Territory (Ozark region). This locality is very strange, and at present is not connected with the main range, no localities being known in Missouri, Arkansas or the larger part of Tennessee (except the eastern extremity). But it is possible that a connection exists here, and if this should be so, this would indicate, as has been said above (p. 121) that the Ozark region is to be included in the original home of the subgenus. *C. monongalensis* apparently is a representative form of *C. carolinus* in southwestern Pennsylvania.

The most puzzling distribution is offered by the remaining three species, of which *C. diogenes* is the most widely distributed. This species has an eastern and a western range on both sides of the Allegheny Mountains. Apparently it has descended from the mountains, that is to say, represents a more highly specialized branch of the original mountain-loving chimney-builders. It has descended into the Atlantic coast plain on the one side, and is found from New Jersey to North Carolina (Cape Fear). On the other side, it has descended westward, and is found from southwestern Pennsylvania over all the states north of the Ohio (also in Kentucky) as far north as Minnesota and Wisconsin, westward to Iowa (also reported from southwestern Wyoming and Colorado), Kansas, and southward to Louisiana. This immense distribution represents possibly the widest known range of any of the species of crayfishes of the United States. The question remains open, whether the eastern and western range of *C. diogenes* is actually connected across the mountains.

Of the other two species, *C. uhleri* clearly is a local form of *C. diogenes*, inhabiting the sea coast (brackish and salt marshes) in Maryland. *C. argillicola* is morphologically very closely allied to *C. diogenes*, and might be regarded, at least in Ohio, Michigan and Canada, as a local form developed at the northern edge of the range of *C. diogenes*. But the fact that *C. argillicola* is also found in central and southern Indiana, in southern Illinois, and that it has been reported from Mississippi and southern Texas (Victoria and Brazoria), does not render this assumption probable: further investigations of the range of these two species (*diogenes* and *argillicola*) in the south and west are desirable, before their mutual geographic relation can be ascertained.

Thus the burrowing species of the *diogenes-section* of the subgenus, while conforming in part to the original habit of living in the mountains, have in another part abandoned their original mountain home, and largely spread over the plains. That this was possible is no doubt due to their peculiar way of living. Aside from *C. gracilis* of the subgenus *Cambarus*, which is also a burrowing form, and occupies a certain part of the western plains, there are no other forms in the central basin that have acquired this habit, and thus *C. diogenes* did not find any competition, and was able to occupy a large territory. That *C. diogenes* is a very vigorous and flourishing form is also demonstrated by the fact that it attains, chiefly on the western plains, a considerable size.

GENERAL CONSIDERATIONS AND CONCLUSIONS.

We have divided the genus *Cambarus* into four subgenera: *Cambarus*, *Cambarellus*, *Faxonius*, *Bartonius*. *Cambarus* originated in Mexico, and immigrated, probably at the beginning of the Tertiary, into the southwestern and southern United States, originally occupying only the southwestern Cretaceous plain, the Ozark Mountains, and the southern extremity of the Appalachian System. A side branch, *Cambarellus*, has also its center in Mexico, and spread, possibly along the sea coast, to Louisiana. In the central and southeastern parts of the United States three new centers developed. The one is a secondary center for the subgenus *Cambarus*, and lies at the foot of the Appalachian Mountains in the lowlands of Alabama and Georgia. Here the more advanced forms of this subgenus took their origin, and spread all over the Atlantic and Gulf coast plain, and further up the Mississippi valley. These are species inhabiting chiefly ponds, lakes, and sluggish streams of the lowlands. Another subgenus, *Faxonius*, developed in the central basin of the three great rivers, spreading over almost all of the Mississippi drainage, and crossing over into the Hudson Bay, Great Lakes, and even into the Atlantic drainages, probably by the aid of shifting divides. The species belonging to this subgenus are chiefly true river species. Finally, a fourth subgenus, *Bartonius*, developed in the mountainous region of the southern Appalachians, probably including also the Ozark region, and from here it spread chiefly over the Appalachian chain in a northeasterly direction as far as New Brunswick. Most of the species belonging

here are inhabitants of smaller mountain streams and brooks. A peculiar group separated from these, the *section of C. diogenes*, which acquired burrowing habits, and is originally also a mountain loving group, but began to descend into the lowlands. Finding no competition here, on account of its peculiar mode of life, it had a chance to spread over a large area.

The centers for the more highly advanced forms of the subgenus *Cambarus*, and for the subgenera *Faxonius* and *Bartonius*, apparently form physiographically differentiated parts of one larger center, situated in the southeast of the United States, clearly corresponding to the southeastern center of dispersal of Adams (*Biological Bulletin*, 3, 1902, p. 115 ff.)[1] Adams discusses this center chiefly with reference to the glacial and postglacial time, but it existed, no doubt, also during the Tertiary, and the development of the different branches of *Cambarus* falls, in my opinion, chiefly into the preglacial time. As Adams maintains, this center is quite distinct from the southwestern center on the arid plateau of Mexico and the adjoining parts of the United States. This latter does not seem to be very important for the later development of the genus, arid regions being generally unfavorable for crayfishes. In older Tertiary times, however, also the southwestern center played a part, in fact it is the original center of the whole genus *Cambarus*.

The different "outlets or highways of dispersal," as Adams (*l. c.*, p. 123) has characterized them, are rather well represented in the distribution of *Cambarus*, and here again I believe, that they were efficient in preglacial times as well as in postglacial times. The Mississippi valley route is represented in the dispersal of the subgenus *Faxonius*, and also by that of the *blandingi-group* of the

[1] Adams' southeastern center does not include the central basin, and he thinks that the Mississippi river (although it undoubtedly possessed a fauna of its own) was largely populated by way of the Tennessee River, which, after having captured the upper course of the old Appalachian River, opened an outlet to its fauna toward the Mississippi. This is no doubt quite correct with reference to the freshwater shells, and, as has been pointed out already by Adams, finds some support in the distribution of certain crayfishes (*l. c.*, p. 849). But as we have seen in the above pages, the center of *Faxonius* in the central Mississippi valley is very marked, and apparently distinct from the other two centers. It is, however, easy to unite all three of them, and regard them as parts of one larger center of older (old Tertiary?) age, including parts that are differentiated physiographically, as indicated above.

subgenus *Cambarus* (*C. blandingi acutus*). The route along the coastal plain seems to be the least frequented, only *C. blandingi typicus* characterizing it. But then again the Appalachian plateau formed a third outlet to the north; this is clearly indicated by the dispersal of the subgenus *Bartonius*. Adams says very pertinently (p. 129): "dispersal is both forward and backward along these highways," and thus we see that in special cases the direction of the migration may become the opposite. In one case (*C. clarki*) we have a reversed current of migration from the southeastern United States toward the southwest, going in a direction opposite to the general direction of immigration of the whole genus. A direction downward the Mississippi valley (southward) is probable in the *palmeri-group* of *Faxonius*, and *C. diogenes* seems to represent the identical reversed direction, descending the Ohio valley from the Allegheny Mountains. The same species shows indications of a reversed migration on the Atlantic coast plain, from Maryland to Virginia.

That the different centers of origin assumed above are very likely correct, is shown by a two-fold consideration. First, the largest number of species of each subgenus is generally found in or near these centers (Adams, *l. c.*, 1902, p. 128: first criterium), and then the more primitive forms of each subgenus are found there (third criterium of Adams). For the subgenus *Cambarus*, this is not entirely true, Mexico possessing only two species, while Kansas possesses three of the more primitive forms, but this may be due to deficiency of our knowledge, or else it is due to interruption and breaking up of the old southwestern range of the genus; it is apparently not so flourishing any more in these parts as it used to be. Of the more highly advanced forms of the subgenus *Cambarus* (*blandingi-section*), the largest number of species is recorded for Georgia (7), Florida (6), and Alabama and Mississippi (4 each). The most primitive forms (*spiculifer-group*) are found in Georgia, Florida and Alabama.

The subgenus *Cambarellus* also makes an exception, two species being found in Mexico, and only one, but this a more primitive one in Louisiana.

The subgenus *Faxonius* possesses the largest number of species in Arkansas (8), and in Missouri and Indiana (7 each). Illinois has only 4, but this may be due to defective knowledge. The more

primitive forms of the *limosus-section* (aside from *C. limosus* itself) are found in Indiana, Kentucky and Missouri, that is to say, in the same general region.

The subgenus *Bartonius* has the largest number of species in Tennessee (6); then follow: Georgia, North Carolina, Virginia and Pennsylvania (with 4 each). The more primitive forms of the *extraneus-section* are found in Georgia, Alabama, Tennessee and Kentucky. In Tennessee is also found one of the blind cave forms (*C. hamulatus*). Thus also here is apparently a mutual relation between center of origin, location of most primitive forms, and center of frequency. This rule, consequently holds good in the section of *C. blandingi* of the subgenus *Cambarus*, and in the subgenera *Faxonius* and *Bartonius*, while it is not very evident in the more primitive forms of the subgenus *Cambarus*, and in the subgenus *Cambarellus*.[1]

A few peculiar and striking facts ought to be mentioned especially.

Discontinuity of distribution proof of antiquity.—We have found this rule substantiated in the following cases: (1) In the distribution of the more primitive forms of the subgenus *Cambarus* (sections of *C. digueti* and *gracilis*); (2) in the subgenus *Cambarellus*; (3) in the *limosus-section* of the subgenus *Faxonius*; (4) in the *hamulatus-section* of the subgenus *Bartonius*. The discontinuity offered by *C. wiegmanni* in the *alleni-group* of the subgenus *Cambarus* needs further investigation, and cannot be regarded as established before the systematic position of this species has been positively ascertained.

Morphologically isolated species occupy isolated stations.—This is illustrated by: (1) *C. cubensis* in Cuba; (2) *C. shufeldti* in Louisiana; (3) *C. limosus* on the Atlantic coast plain from New Jersey to Virginia; (4) *C. harrisoni* in Missouri; (5) *C. alabamensis* and *compressus* in northern Alabama: (6) *C. setosus* in Missouri (cave-form).

Closely allied species occupy neighboring areas. —This is most evi-

[1] Addition to our knowledge may change this considerably. I only call attention to the fact, that up to very shortly ago only two species of *Bartonius* were known from the state of Pennsylvania. Investigations during the last four years have revealed the presence of two more species, thus doubling the number. This may happen in any other state.

dent in the following cases, where groups of species occupy a certain range, but represent each other in the different parts of this range: (1) in the *spiculifer-group* of the subgenus *Cambarus: spiculifer* in northern and central Georgia, *versutus* in central and southern Alabama, and in northwestern Florida, *pubescens* in eastern Georgia, *angustatus* in southeastern Georgia. (2) In the *clarki-group: clarki,* parallel to the Gulf coast from Texas to Florida, *troglodytes* in corresponding localities in Georgia and South Carolina. (3) *Limosus-section* of *Faxonius: indianensis* in southwestern Indiana, *sloanei* in southeastern Indiana and Kentucky. (4) *Propinquus-group: propinquus* has a western and northern distribution; it is represented in western Pennsylvania by *obscurus.* (Between both possibly is *C. propinquus sanborni,* occupying an intermediate range.) (5) *Rusticus-group: spinosus* is southern and eastern (North and South Carolina, northern Georgia, northern Alabama and eastern Tennessee), while *putnami* is more northern (Kentucky). (6) In the *palmeri-group* the different species occupy different parts of a range that includes Mississippi, western Tennessee, Arkansas, Indian Territory and northeastern Texas.

Groups of allied species are often formed by a typical species, which shows a wide range, while the allied species form a fringe on the edge of this range thus representing local forms. This is shown beautifully in the following natural groups: (1) *Rusticus-group:* the typical form is *rusticus,* the local forms at the edge of its range are: *forceps* (southeast), *neglectus* (west and southwest), *spinosus* and *putnami* (southeast), *hylas* (south), *medius* (south); probably also *erichsonianus* (southeast). (2) *Virilis-group:* the typical form is *virilis,* the local forms are: *meeki, longidigitus, nais, pilosus,* all in the southwest. (3) *Bartoni-section: bartoni* is the typical form, the local forms of it are: *acuminatus* (southeast), *latimanus* (south and southwest); in this section also a mountain form has developed within the range (*longulus*), and varieties are found in the southern section of the range, as well as at its northwestern edge. (4) *C. monongalensis* is a local form developed at the northwestern edge of the range of *C. carolinus.* (5) In the *diogenes-section,* at least one species, *C. uhleri,* seems to be a local form of the widely distributed *C. diogenes,* developed at the eastern extremity of its range.

More or less closely allied species, occupying the same or nearly the same territory, generally possess different habits. In most of the

species, we do not know much about their habits, but a few remarkable cases may be mentioned. (1) *C. virilis* and *C. immunis*, although sharply separated, are rather closely allied, and occupy large identical tracts of the central states. We know that *C. virilis* prefers running water with stony bottom, while *C. immunis* is a pond and ditch form (see above, p. 117). (2) *C. monongalensis* inhabits, in western Pennsylvania, almost the same territory that is occupied by *C. diogenes*. The first, however, belongs to the hills, the second to the lowlands (see Ortmann, *Ann. Carnegie Mus.*, v. 3, p. 400).

The various drainage systems have a different effect upon the species of the different subgenera, which is apparently due to fundamental differences in their habits. (1) *Bartonius* is preëminently a mountain-stream group. It goes up into the smallest streams, up to their very sources. In this region, changes of drainage, due to piracy, are common, and rather the rule than the exception, and thus the species quite generally occupy the headwaters of streams running in different directions from the divides. This is exampled by the distribution of the following species: *extraneus*, *bartoni*, *longulus*, *latimanus*, *carolinus*, and probably also by *diogenes*. (See Adams, "Migration of Divides," in *Americ. Natural.*, 35, 1901, p. 844). (2) The *blandingi-section* belongs originally to the lowlands of ths Gulf and Atlantic plain. Here removal of barriers largely has taken place, and thus the species of this group belong to the drainages of different coast rivers, for instance: *lecontei blandingi*, *clarki*, *troglodytes*, *alleni*. (See Adams, *ibid.*, p. 842: "In a country approaching base-level a wide distribution of the fauna will be facilitated.") (3) The subgenus *Faxonius* belongs to the great rivers of the interior basin, and does not ascend far into the headwaters, at least in the mountainous regions, and also does not descend far toward the coastal plain. Consequently, the drainage systems being more permanent, the distribution of these species is more closely connected with the latter. We may, perhaps, compare this — in a very general way — with the period of maximum roughness of Adams (*l. c.*), although this does not hold good for all of this immense region. Indeed, there are important exceptions, and the subgenus has crossed over into the lake-drainage (*C. propinquus*, *obscurus*, *rusticus*, *virilis*, *immunis*), and even into the Hudson Bay drainage (*C. virilis*). This has been brought

about, apparently, by extensive shifting of divides, and we know positively, that this has taken place in great style during and after glacial times. The eastern mountains (Appalachian system) have formed a sharper barrier, but also here certain species have been able to cross: in ancient times *C. limosus*, in more recent times *C. obscurus* (see Ortmann, *Ann. Carn. Mus.*, v. 3, p. 406). The most interesting region is at the southern extremity of the Appalachian system, as we shall presently see.

Very important drainage changes, that have taken place in the southern Appalachian system, are clearly indicated by the distribution of crayfishes, and tend to confirm the results obtained by Simpson and Adams for the freshwater mollusks (see above p. 116). In the region of the Alabama River drainage and that of the Tennessee River, we had at a certain time, a large river running to the South, the Appalachian River, the upper course of which was deflected toward the Northwest, forming the present Tennessee River. The former unity of the drainage system is indicated by identical or closely allied species found now in both systems. The following species illustrate this: *C. erichsonianus, extraneus, jordani, latimanus*, and possibly others. Further investigations of the conditions present in these regions are very desirable.

This is, I think, a rather satisfactory outline-sketch of the distribution of the genus *Cambarus* over the United States. But it is only a sketch, and more detailed investigations are much needed. We see that the migrations of the different groups are very complex, the directions of the migrations crossing at various angles, often being directly opposed to each other. (See map, plate III.)

Further, we are to emphasize, that our knowledge is by no means complete with regard to the distributional facts. There is hardly a single case, where the actual boundaries of a species are known. We have a large number of locality-records, and by plotting them on a map, we obtained a general idea of the range of the different species, but rarely we know the exact limits, and nobody has ever tried to ascertain these, except the present writer in a very limited region, in western Pennsylvania (see *Ann. Carnegie Mus.*, v. 3, 1905). But this ought to be done by all means, and there is no doubt, that very interesting results will be obtained.

It may be remarked in conclusion, that I do not think that a number of reported localities for certain species are trustworthy.

It is astonishing how easy records and museums specimens become mixed up, and a number of localities which are given bona fide by various authors are very questionable. In the following, I put together those records, that appear — at least to me — doubtful or in need of confirmation. At the same time, a number of new records is given which have been made use of in the above pages.

C. blandingi (Harl.).

New Localities. — Millpond at Plainsboro, Middlesex Co., New Jersey, coll. by the writer (Carn. Mus.). — This species is further abundant in the millpond of Grover's Mills, Princeton Junction, Mercer Co., N. J. (seen by the writer), and is rare in the Delaware-Raritan Canal, at Aquæduct near Princeton, Mercer Co., N. J. (seen by the writer).

C. clarki Gir.

New locality. —Devils River, Val Verde Co., Texas, coll. by H. A. Pilsbry, 1903 (specimens in Philadelphia Acad. and Carn. Mus.).

C. limosus (Raf.).

New localities. — Stony Brook, Princeton, Mercer Co., N. J., coll. by the writer, May 30 and Sept., 1898 (Carn. Mus.). — Delaware-Raritan Canal, at Aquæduct near Princeton, Mercer Co., N. J., coll. by the writer, Jan., 1899 (Carn. Mus.). — Delaware River, North Cramer Hill, Camden Co., N. J., coll. by the writer, Sept. 18, 1904 (Carn. Mus.). — Collected by the writer at the following new places in Eastern Pennsylvania in September, 1904: Delaware River, Torresdale Fish Hatchery, Torresdale, Philadelphia Co.; Marcus Hook Creek, Marcus Hook, Delaware Co.; Little Neshaminy Creek, Grenoble, Bucks Co.; Delaware River, New Hope, Bucks Co.; Schuylkill River, West Manayunk, Montgomery Co. (Carn. Mus.). — Further: Tributary of Brandywine Creek, Chadds Ford Junction, Chester Co., Pa. (Acad. Philad.). — Delaware River at Holmesburg, Philadelphia Co., Pa. (Acad. Philad. and Carn. Mus.). — Gettysburg, Adams, Co., Pa., coll. by H. A. Pilsbry (Acad. Philad.). — Potomac River, Cherry Run, Morgan Co., W. Va., coll. by the writer, Sept. 23, 1904 (Carn. Mus.).

Doubtful and spurious older records. — Hagen gives, in 1870, Niagara (L. Agassiz); Lake Erie; New York (Mr. Pike); and Pittsburg. Faxon (1885) drops New York and Pittsburg, but

again gives Niagara (" there is no doubt of the correctness of the determination"), and Lake Erie (Peabody Ac. Sci.). In 1890, Faxon says of the latter specimens, that they "are too small to determine with certainty." He further gives, in 1885, Lake Superior (Boston Soc. Nat. Hist.). I do not entertain the slightest doubt that all these localities are wrong. As to Niagara, which is founded upon the authority of L. Agassiz, we only have to consider that the same locality upon the same authority is given also for *C. propinquus*, and it is quite probable, that specimens of *C. limosus* were put by mistake into a jar containing *C. propinquus*. As to Lake Erie and Lake Superior, some other species may be intended, or a similar mistake has been made: I do not believe, most emphatically, that this species is found in the lake-region. With regard to the absence of *C. limosus* in the state of New York, we possess the testimony of De Kay (Zoöl. N. Y., 6, 1844, p. 23): "I have searched for it (*Astacus affinis*) without success in the tributaries of that stream (Delaware) within the limits of this State."

C. propinquus Gir.

New Localities. — Lake Erie, Lorain Co., Ohio, Lorain gill nets. May 1, 1892, coll. by H. Warden (Mus. Oberlin). These specimens from the lake are the true *C. propinquus*, while all other specimens from the tributaries of the lake in Lorain Co., Ohio, belong to *propinquus sanborni*, see below. Crooked Lake, Oden near Petoskey, Emmet Co., Mich., coll. by E. B. Williamson, Sept. 1, 1904 (Carn. Mus.). This is the northernmost exact locality known, and is very near to a locality recorded by Ward (Bull. Mich. Fish Comm., 6, 1896, p. 15), but not recorded by Faxon, namely: Lake Michigan and Pine Lake at Charlevoix, Charlevoix Co., Mich.

Doubtful Locality. — The latter localities in northern Michigan render it possible that the old records of Lake Superior, given by Hagen on the authority of L. Agassiz, may be correct. But since to L. Agassiz also the record of *C. rusticus* and *virilis* for Lake Superior are attributed, we have again several species mixed up, and it is better to wait for a confirmation.

C. propinquus sanborni Fax.

New Localities. — Oberlin, Lorain Co., Ohio, is the type-locality (Faxon) for this form. I have seen it (Mus. Oberlin) from the

following localities in this region and the state of Ohio: Waterworks reservoir, Oberlin, and Plum Creek, Oberlin; further: Vermillion River, Beaver Creek, French Creek, all in Lorain Co.; Killbuck Creek, Creston, Wayne Co.; Tuscarawas River, Gnadenhutten, Tuscarawas Co. The latter two localities belong to the Ohio drainage, while the rest is lake drainage. This variety forms a morphological link between *C. propinquus typicus* and *C. obscurus*, and seems to be intermediate also in its range.

C. rusticus Gir.

The locality Lake Superior (L. Agassiz) given by Hagen (1870) needs confirmation. As I have shown elsewhere (Ann. Car. Mus., v. 3, 1905, p. 387), the locality Pittsburgh is wrong.

C. neglectus Fax.

New Locality.—Rogers, Benton Co., Arkansas, coll. by H. A. Pilsbry, March 25, 1903 (Acad. Philad. and Carn. Mus.).

C. putnami Fax.

New Locality.—Rockcastle River, Livingston, Rockcastle Co., Ky., coll. by E. B. Williamson, June 21, 1904 (Carn. Mus.). (See Williamson, Ohio Natural., 5, 1905, p. 311.)

C. virilis Hag.

New Locality.—Sandy Lake, Ontario, Canada, coll. by G. H. Clapp (Carn. Mus.). This species has been reported by Ward (Bull. Mich. Fish Comm., 6, 1896, p. 15) from Lake Michigan and Pine Lake, Charlevoix Co., Mich.

The locality Lake Superior, given on the authority of L. Agassiz by Hagen (1870), has been confirmed by Faxon (1885) on the authority of C. L. Herrick, and falls within the known range of the species.

Doubtful Records.—Lake George, N. Y. (L. Agassiz) has been recorded by Faxon (1885) with a ?. It surely is very doubtful.

Faxon also mentions this species from Laramie City in Wyoming; this may be correct, but needs confirmation. He records it further from near Bridgeport, Jackson Co., in northern Alabama, in the Tennessee drainage (U. S. Mus.); I seriously doubt the correctness of this locality, since it is the only one east of the line formed by the Mississippi and Ohio rivers, and is far remote from the rest of the range.

C. immunis Hag.

New Localties.—Lamoni, Decatur Co., Iowa, coll. by J. B. Hatcher (Carn. Mus.). This species is also found in northern

Ohio, as first indicated by Osburn and Williamson (6 Ann. Rep. Ohio Ac. Sci., 1898, p. 21), in Sandusky, Erie, and Lorain Cos., and in Lake Erie. I have seen specimens (Mus. Oberlin) from Huron River, Huron, Erie Co., and from Oberlin, Lorain Co. (Waterworks Reservoir and Plum Creek).

Doubtful Records. — Hagen (1870) gives Huntsville, Madison Co., northern Alabama. This is possibly not this species, at any rate it is "not normal" (Faxon, 1885, p. 100). The locality is too far separated from the rest of the range, to be accepted without hesitation.

Faxon (1885) gives: New York (L. A. Lee); Laramie, Wyoming (U. S. Mus.); Orizaba, Mexico (U. S. Mus.), and further in 1898 he adds: small stream flowing into Oneida Lake, N. Y. The locality in Wyoming may be correct, but we have to try to connect it with the rest of the range, before accepting it. Orizaba, Mexico, is no doubt wrong, and I do not hesitate for a moment to drop it. Oneida Lake in New York seems very strange, since there are no connecting localities with northwestern Ohio. I cannot accept this locality unless verified by unequivocal evidence.

C. palmeri longimanus Fax.

New Locality. — Limestone Gap, Choctaw Mt., Indian Terr., coll. by H. A. Pilsbry (Ac. Philad. and Carn. Mus.).

C. extraneus Hag.

New Locality. — Rockcastle River, Livingston, Rockcastle, Ky., coll. by E. B. Williamson, June 21, 1904 (Carn. Mus.). This is in the Cumberland River drainage; previously, this species was known only from Tennessee, Alabama and Georgia. (See Williamson, Ohio Natural., 5, 1905, p. 310.)

C. bartoni (F.).

New Localities. — Small streams, Princeton, Mercer Co., N. J., coll. by the writer (Carn. Mus.); East Canada Creek, Herkimer Co., N. Y., coll. by R. Ruedemann (Carn. Mus.); Selbysport, Garret Co., Md., coll. by the writer (Carn. Mus.); Cherry Run, Morgan Co., W. Va., coll. by the writer (Carn. Mus.); Greenville, New Castle Co., Del. (Ac. Philad.). The following localities in eastern and central Pennsylvania are represented in the Carnegie Museum (coll. by the writer): Driftwood and Sinnamahoning, Cameron Co.; Keating Summit, Potter Co.; Wills Creek, Mance, Somerset Co.; Cush-Cushion Creek, Indiana Co.; Cresson, Cambria Co.; Ashville, Cambria Co.; Hollidaysburg, Blair Co.;

Wissahickon, Philadelphia Co.; Shoemakersville, Berks Co.; Valley Forge, Chester Co.; Grenoble, Bucks Co.; New Hope, Bucks Co.; West Manayunk, Montgomery Co.; Wallingford, Delaware Co. Other new localities in eastern Pennsylvania are: Headwaters of Loyalsock Creek and Ganoga Lake, Sullivan Co. (Ac. Philad.); Pinegrove, Cumberland Co. (Ac. Philad.).

Doubtful Record. — Lake Superior, given by Hagen on the authority of L. Agassiz, is undoubtedly wrong. As to records of this species from Ohio see *C. bartoni robustus.*

C. bartoni robustus (Hag.).

New Localities. — Small stream tributary to Rockcastle River, Livingston, Rockcastle Co., Ky., coll. by E. B. Williamson, June 21, 1904 (Carn. Mus.). These specimens agree well with young individuals of this variety; adult ones are not in the lot. (See Williamson, Ohio Natural., 5, 1905, p. 310.) Oberlin, Lorain Co., Ohio (Mus. Oberlin). This form was doubtfully reported from Knox Co., Ohio, by Osburn and Williamson (1896). All specimens from Oberlin seen by the writer belong to this variety. The typical form seems to prevail in southern Ohio.

Doubtful Records. — Faxon (1885) gives Decatur, Macon Co., Ill., but this needs confirmation. Further it is doubtful, whether the form called by this name in Maryland and Virginia is identical with the true (northern) *robustus.*

C. bartoni longirostris (Fax.).

Doubtful Record. — Pollard, Escambia Co., Alabama, seems doubtful, since it is close to the Gulf coast, and far away from the original mountain home of this form.

C. latimanus (Lec.).

The locality, Ocean Springs, Miss., is doubtful for the same reason.

C. carolinus Er. (= *dubius* Fax.).

The reported occurrence of this species in Indian Territory (Faxon, 1890) seems strange. It must be looked upon as doubtful till the connection with the rest of the range is established.

C. diogenes Gir.

New localities. — Cooper, Greene Co., Iowa, coll. by J. B. Hatcher (Carn. Mus.); Seaford, Sussex Co., Delaware, coll. by S. N. Rhoads, June 18, 1903 (Ac. Philad. and Carn. Mus.). —Oberlin, Lorain Co., Ohio (Mus. Oberlin). —The specimens from this locality have been mentioned by Osburn and Williamson (1898) as *C. dubius ?*, but they are typical *C. diogenes.*

Doubtful records. — Faxon, 1885, gives Deer Park, Garrett Co., Md. This should be confirmed; according to the writer's experience, *C. carolinus* ought to be expected there. If confirmed, this locality will be highly interesting.

Faxon further gives: Cheyenne, Wyoming, and Clear Lake, Colorado; in both cases the most western extremity of the range of the genus is reached. Harris (Kansas Univ. Quart., 9, 1900, p. 267) gives: Boulder, Colorado. This serves to establish the correctness of the above records, but the connection with the rest of the range must be found (I have not been able to locate Clear Lake in Colorado). The southern localities for *C. diogenes* recorded by Faxon, Monticello, Lawrence Co., Miss., and New Orleans, Louisiana, certainly need further support.

C. argillicola Fax.

New locality. — Oberlin, Lorain Co., Ohio (Mus. Oberlin). — I have seen three specimens from Oberlin (adult and young male, adult female), two of which bear the label: Hovey's Ice house, northeast of Oberlin, coll. by Leuthi, Sept. 29, 1892.

Doubtful records. — The localities, Kinston, N. Carolina, and New Orleans, Louisiana, given by Faxon in 1885 are doubtful, as admitted by himself. The localities given in 1898, Victoria and Brazoria, Texas (U. S. Mus.), most emphatically need confirmation.

CARNEGIE MUSEUM,
PITTSBURGH, April 7, 1905.

EXPLANATION OF PLATE VIII.

The plate is introduced to illustrate the *centers of origin*, and the *chief directions of migration* of the different subdivisions of the genus *Cambarus*. Circles or ellipses indicate centers of origin, the lines radiating from these, and ending in an arrow-point, indicate the migration. The different colors mark the different subgenera: *Red*, *Cambarus*; *brown*, *Cambarellus*; *green*, *Faxonius*; *blue*, *Bartonius*.

It will be remarked that two centers are given for the subgenus *Cambarus*: the one in Mexico marks that of the more primitive forms, the other in Alabama and Georgia, that of the more highly advanced forms (*blandingi-section*). This latter one, as well as the subgenera *Faxonius* and *Bartonius*, took their origin probably from a primitive stock of the subgenus *Cambarus*, immigrated into the southern United States along the broken red line running from Kansas to Alabama.

For further particulars see text, pp. 103, 106, 113, 121, and 124 ff.

to illustrate the centers of origin and the chief directions of migration of the different subdivis
of the genus Cambarus.

[Contribution from the John Harrison Laboratory of Chemistry.]

THE USE OF THE ROTATING ANODE AND MERCURY CATHODE IN ELECTRO-ANALYSIS.

BY LILY G. KOLLOCK AND EDGAR F. SMITH.

(*Read April 13, 1905.*)

FIRST PAPER.

Several investigations made in this laboratory have shown that when in electro-analysis the anode is rotated high currents can be used and metals be precipitated completely in very short periods of time; further, by the use of mercury cathodes most interesting determinations and separations of metals are possible.[1] In the latter case, however, the anode has been stationary, and the electrolyte consequently not agitated. Then, of course, the precipitation of the metal has been comparatively slow. Observing the splendid results got with the rotating anode, when platinum was the cathode, we determined to use a combination of rotating anode and mercury cathode. This was accordingly done, and in some preliminary trials made last August (1904), the results of which were briefly alluded to in a communication published in the *Jour. Am. Chem. Soc.*, **26**, 1614, mention was made that 0.4810 gram of copper could be precipitated in twenty-five minutes, and that this success could be had with other metals. Since then we have made additional experiments which we desire to record here. Not only is the time factor reduced for the metals studied, but the plan of combining a mercury cathode with the rotating anode gives an inexpensive form of apparatus which will eliminate the platinum dish, cone or cylinder from electro-analysis and thus remove an expensive factor.

Apparatus. — The decomposition cell is a tube 3.5 cm. in diameter and 7.5 cm. in height, made from a test tube. Soften the bottom of the tube in a blast lamp flame, then push through it a platinum wire two centimeters in length, so that its end projects 0.5 cm. into the tube. Flatten the bottom of the tube on an asbestos plate and anneal it in the ordinary way.

[1] *Jour. Am. Chem. Soc.*, **25**, 884: **26**, 1124.

The anode, 7.5 cm. in length, is made from platinum wire 1 mm. in diameter, coiled into a flat spiral 1.5 cm. in diameter. It is inserted in a chuck carried by the rotator which is also provided with three pulleys varying from 2 to 5 cm. in diameter. These pulleys are connected by a belt to two pulleys on the motor. With this arrangement the rotation of the anode could be varied from 100 to 1800 revolutions per minute. During the decomposition an amperemeter, a voltmeter and a rheostat, allowing of resistance from .1 to 100 ohms, were kept in the circuit.

The precautions indicated by Myers in his paper with regard to the decomposition cell were observed. If care be taken to have the cell as clean as possible there will be no trouble experienced with the amalgam subsequently adhering to its sides. The mercury, before using, should be washed with alcohol and ether and after the odor of the latter has disappeared, be placed in the desiccator until it is weighed. It was generally allowed to remain for about five minutes on the balance pan before taking the final weight. In practice a beaker containing a large quantity of mercury, so prepared, should be kept in the desiccator ready for use. The mass of the mercury taken in a single experiment varied from forty to fifty grams. This was frequently used for two or three determinations, except in the case of chromium, where it was found advisable to use it but once. The cathode surface in the first experiments upon zinc was 3.5 sq. cm., but throughout the rest of the work it was about 9 sq. cm. After weighing the decomposition cell and mercury, the solution to be electrolyzed should be introduced. The volume of the electrolyte is always recorded in the accompanying tables. The cell should then be placed upon the copper plate and the anode lowered into the solution. The distance between the cathode and anode depended upon the volume of the electrolyte. When the volume was five cubic centimeters the electrodes were .5 cm. apart and in other instances 1 cm. was their distance apart. The difference did not appear to materially affect the rate of deposition. The tube should be covered. The anode should next be rotated and the connection made with the required number of chloride accumulator cells. The speed of the anode was varied either by using less current for the motor or by changing the combination of pulleys. With the higher currents recorded, the solution was frequently heated to boiling. When this occurred the

current invariably dropped sometimes as much as one ampere. But upon washing down the cover glasses with cold water it rose to its former strength. The dropping of the current is probably due to the accumulation of steam bubbles upon the electrodes. During the electrolysis some of the solution will of course be carried to the sides of the containing vessel and to the cover glasses by the escaping gases or by the agitation of the liquid. After many trials it was found that it is unnecessary to wash down this portion when the higher currents are used. The condensed steam continually frees the sides from the solution. The cover glasses may now and then be tilted against the sides of the tube in order to run off the water which collects in large drops.

It has been repeatedly observed in the present work that the greater the concentration of the electrolyte, the greater the rapidity of deposition, but the last traces of metal were always difficult to remove. For this reason, after a solution had become colorless, the electrolytic action was continued several minutes in order to precipitate the minute amount remaining unprecipitated. It is, therefore, also important to have the volume small toward the end of the decomposition.

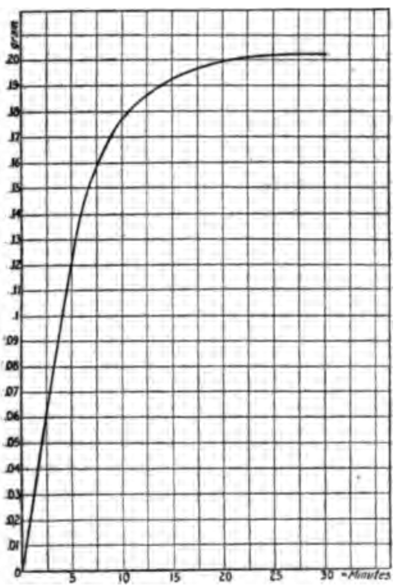
When the metal has been completely deposited, the anode should be stopped, the cover glasses removed and the decomposition cell filled with distilled water. This should then be siphoned off to the level of the spiral and the liquid replaced by distilled water until the current drops to zero. This wash water should always be put aside and tested in order to ascertain that the metal has been completely deposited. The current should next be interrupted and the tube removed and washed again with distilled water, inclining and twirling the cell in order to more completely wash the amalgam. As much of the water as possible should be poured from the cell and the amalgam then be washed twice with absolute alcohol and twice with ether. It should be wiped dry on the outside and after the volatilization of the ether be placed in the desiccator and weighed as previously described.

Experimental Part.

Zinc.

The first experiments made after those described in the *Jour. Amer. Chem. Society* **26**, 1614, were upon zinc sulphate. They

were conducted in order to ascertain the rate of deposition with varying concentration, current strength, electromotive force, speed of anode and how the quantity of metal in the mercury affected the subsequent rate of deposition. The solution for the first experiments contained 0.2025 gram of metallic zinc in 10 cc. This was determined by the electrolytic method, depositing it upon a platinum dish from an ammonium acetate electrolyte. The speed of the anode was 400 revolutions per minute. The current strength was one ampere and the E.M.F. was 5 volts. The volume of the zinc sulphate solution equaled 15 c.c., the current acted thirty minutes. The solution siphoned from the tube showed no trace of zinc. Consecutive experiments so conducted gave the following results in 25 minutes: .2027, .2030, .2025, .2025, .2021, .2027, .2025 grams. Two trials were made with the same conditions but using a volume of 10 c.c. instead of 15 c.c. It was found that the zinc was completely separated in twenty minutes.



CURVE I. Zinc—1 Ampere, 5 volts.

Experiments were then made to determine the rate of deposition in successive periods of time and the curve constructed from the data thus obtained, using periods of time for abscissas and masses for ordinates. The conditions employed were those given above. The results were as follows:

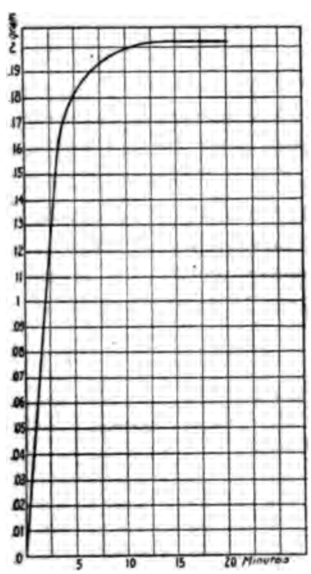
In 5 minutes	0.1196 gram.
" 10 "	0.1774 "
" 15 "	0.1897 "
" 20 "	0.2002 "
" 25 "	0.2027 "

Upon employing a current of 2 amperes, adding sulphuric acid to increase the conductivity, the entire amount was deposited in

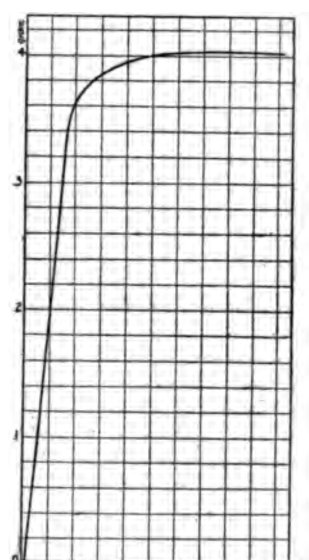
15 minutes. The following conditions were employed: Total volume 15 c.c., sulphuric acid 0.4 c.c., current strength 2 amperes, pressure 7 volts, speed of anode, 500 revolutions per minute.

In 5	minutes	0.1860	gram	of	zinc	was	deposited.
" 10	"	0.1998	"	"	"	"	"
" 15	"	0.2020	"	"	"	"	"

Double the quantity of zinc mentioned above was dissolved in 15 c.c. To this was added .25 c.c. of concentrated sulphuric acid, the anode was rotated at the rate of 800 revolutions per minute and the solution electrolyzed. In thirty minutes the zinc was completely deposited, using a current of 1.5 amperes and 10 volts.



CURVE 2. Zinc — 2 Amperes, 7 volts.



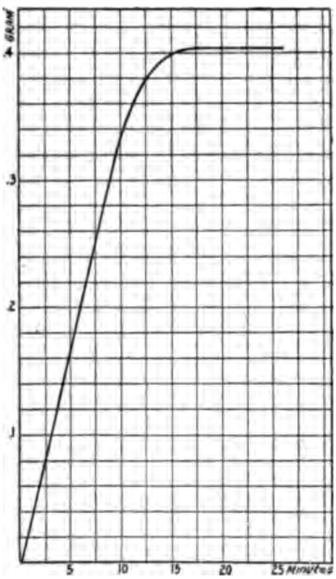
CURVE 3. Zinc–2 Amperes, 6 volts

In 10	minutes	0.3701	gram	was	deposited.
" 15	"	0.3997	"	"	"
" 20	"	0.4011	"	"	"
" 30	"	0.4058	"	"	"

Curve 3 was drawn from these results.

The same mass of zinc in twenty cubic centimeters was electrolyzed with a current of 2 amperes and 6 volts, other conditions being identical.

In 10 minutes 0.3352 gram was deposited.
" 15 " 0.4010 " " "
" 20 " 0.4030 " " "
" 30 " 0.4050 " " "



CURVE 4. Zinc—1.5 Amperes, 10 volts.

Curve 4 was drawn from these results. A comparison of the third and fourth curves shows the effect of greater dilution upon the quantity of zinc deposited in the first ten minutes.

Two experiments were made to learn the effect of different speeds of the anode upon the rate of precipitation. It was found that the amount of zinc deposited under a rotation of 440 revolutions per minute, and 1,000 revolutions per minute was only .0004, which is within experimental error, showing that between these limits there is no apparent effect. It was also discovered that when more than 1 gram of zinc was present in the mercury, the latter should not be further used if it is desired to obtain results in the shortest period.

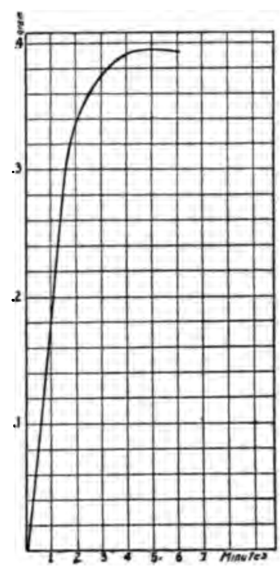
Zinc.

Experiment.	Zinc Present in Gram.	Sulphuric Acid Present in c.c.	Volume in c.c.	Current. Amperes.	Volts.	Revolutions of Anode Per Minute.	Time in Minutes.	Zinc Found in Gram.	Error in Gram.
1	0.2025	0	15	1	7	750	30	0.2027	+0.0002
2	"	0	15	1	7	750	25	0.2030	+0.0005
3	"	0	15	1	7	750	25	0.2015	—0.001
4	"	0	15	1	7	750	25	0.2020	—0.0005
5	"	0	15	1	7	750	25	0.2025	——
6	"	0	10	2	7	750	25	0.2024	—0.0001
7	"	.25	10	2	7	750	30	0.2027	+0.0002
8	0.4050	.25	20	1.5	6	750	45	0.2054	+0.0004
9	0.2025	.25	10	1	5	750	25	0.2025	——
10	"	.25	10	1	5	750	25	0.2029	+0.0004
11	"	.25	15	1	5	750	25	0.2025	——
12	"	.25	15	1	5	750	20	0.2027	+0.0002
13	"	.25	15	2	6	750	15	0.2030	+0.0005
14	"	.25	15	2	6	750	15	0.2020	—0.0005
15	"	.25	15	2	6	750	15	0.2021	—0.0004
16	0.4050	.25	15	5	8	1400	6	0.4057	+0.0007
17	"	.25	15	5	8	480	6	0.4045	—0.0005
18	"	.25	15	5-6	7-5	480	8	0.4042	—0.0008
19	"	.25	10	5	7	640	5	0.4050	——

To 10 c.c. of the zinc sulphate solution 0.4 c.c. of concentrated sulphuric acid was added, after which it was electrolyzed by a current of 5 amperes and 7 volts; the speed of the anode being 640 revolutions per minute. Under these conditions 0.405 gram of zinc was precipitated in five minutes.

Copper.

Having found that .405 gram of zinc could be deposited in from five to eight minutes it was decided to try other conditions upon copper than those recorded in the previous paper, in order to reduce the time factor. By using higher currents and greater concentration of the electrolyte this was accomplished.



Curve 5. Copper—5 Amperes, 6 volts.

A solution of copper sulphate containing 0.3945 gram of metallic copper in five cubic centimeters was used for these experiments. This quantity of metal was precipitated finally in five minutes. The solution became colorless in three minutes. Twice this quantity (.789 gram) was deposited in ten minutes, although the solution had become colorless at the expiration of seven minutes. The volume in this case being ten cubic centimeters it appeared the last traces of copper required more time for precipitation. A current of 5 amperes and 6 volts was used, sulphuric acid being introduced to increase the conductivity.

The current strength recorded in the following table was maintained during the greater part of the electrolysis. When it showed a tendency to rise, on the liberation of the acid, additional resistance was thrown into the circuit. The following rates of deposition of copper were determined under the preceding conditions. The anode made 640 revolutions per minute.

In 1	minute	0.1800	gram	of	copper	was	deposited.
" 2	"	0.3400	"	"	"	"	"
" 3	"	0.3664	"	"	"	"	"
" 4	"	0.3945	"	"	"	"	"
" 5	"	0.3945	"	"	"	"	"

Copper.

Experiment.	Copper Present in Gram.	Sulphuric Acid Present in c.c.	Volume in c.c.	Current. Amperes.	Volts.	Revolutions of Anode per Minute.	Time in Minutes.	Copper Found in Gram.	Error in Gram.
1	0.7890	.25	12	3.5	6	1200	10	0.7900	+0.001
2	0.3945	.15	12	4	6	1080	5	0.3941	—0.0004
3	0.3945	.25	12	3.5	6	1200	6	0.3942	—0.0003
4	0.3945	.15	12	5	6.5	1200	5	0.3944	—0.0001
5	0.3945	0	10	2–4	9–7	1200	6	0.3946	+0.0001
6	0.3945	.17	10	3.5	8.5	1200	4	0.3944	—0.0001
7	0.3945	.17	10	4	6	1080	5	0.3946	+0.0001

Nickel.

A nickel sulphate solution containing 0.4802 gram of metal in ten cubic centimeters was used in the following experiments, and after finding that this quantity was completely deposited in the mercury in twenty minutes with a current of 2 amperes and 7 volts, the rate of deposition in succeeding periods of time was determined with a current of 2.5 amperes and 6 volts.

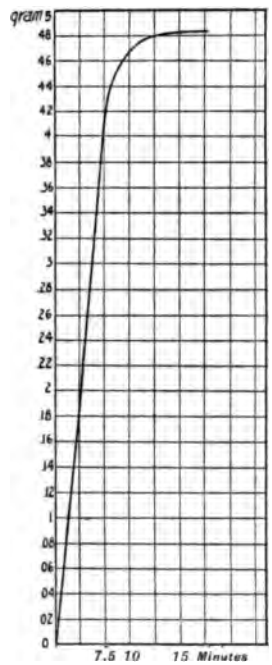
In 2.5 minutes 0.2017 gram of nickel was deposited.
" 7.5 " 0.4095 " " " " "
" 10 " 0.4651 " " " " "
" 12.5 " 0.4774 " " " " "
" 15 " 0.4802 " " " " "

Nickel.

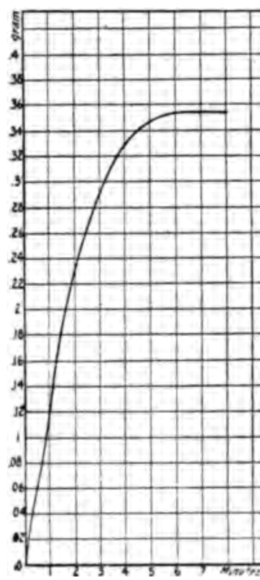
Experiment.	Nickel Present in Gram.	Sulphuric Acid in c.c.	Volume in c.c.	Current. Amperes.	Volts.	Revolutions of Anode per Minute.	Time in Minutes	Nickel Found in Gram.	Error in Gram.
1	0.4802	.25	18	2	7	600	18	0.4802	——
2	0.4802	.25	12	3.5	7	600	16	0.4799	—0.0003
3	0.4802	.25	12	2–4	6.5	600	10	0.4806	+0.0004
4	0.4802	.25	12	6	5	500	7	0.4804	+0.0002
5	0.4802	.25	12	5	6.5	600	10	0.4796	—0.0006
6	0.9604	.25	10–30	4	6	1100	10	0.9597	—0.0007
7	0.4802	.25	12	3	7–5	1100	10	0.4806	+0.0004
8	0.4802	.25	12	3	7	1100	10	0.4796	—0.0006
9	0.9604	.25	12	3.5	7	1100	16	0.9604	——
10	0.4802	.25	12	5	7	640	12	0.4809	+0.0007
11	0.4802	.25	12	5	6	880	8	0.4806	+0.0004
12	0.4802	.25	7	6	5	1200	9	0.4801	—0.0001
13	0.4802	.25	7	6	6	1200	7	0.4801	—0.0001

On employing a current of 6 amperes and a pressure of 5 volts the solution became colorless in four minutes. Not a trace of

nickel was found in the liquid after seven minutes. The amalgam was very bright and of the consistency of soft dough, when one gram of nickel was combined with the usual quantity of mercury (40 grams).



CURVE 6. Nickel—2.5 Amperes, 6 volts.



CURVE 7. Cobalt—5 Amperes, 5 volts.

COBALT.

This metal does not appear to enter the mercury with the same rapidity as nickel under similar conditions. The last minute traces are more difficult to remove. Various conditions were used. When no sulphuric acid was added the current was at first low, but it rapidly rose as the decomposition proceeded. The conditions, giving the total cobalt in the least time, were the following: 10 c.c. of solution, containing 0.3535 gram of cobalt; 0.25 c.c. of sulphuric acid and a current of 5 amperes with a pressure of 6 volts. The speed of the anode was 1,200 revolutions per minute. The solution became colorless in seven minutes, but ten minutes appeared to be necessary for the removal of the last traces of the

metal. On using the same amount of cobalt in a volume of five cubic centimeters, other conditions remaining unchanged, all of the metal separated in seven minutes, thus:

In 1 minute 0.1197 gram. of cobalt was deposited.
" 3 " 0.2930 " " " " "
" 5 " 0.3300 " " " " "
" 6 " 0.3520 " " " " "
" 7 " 0.3535 " " " " "
" 10 " 0.3530 " " " " "

The curve (7) was constructed from these results.

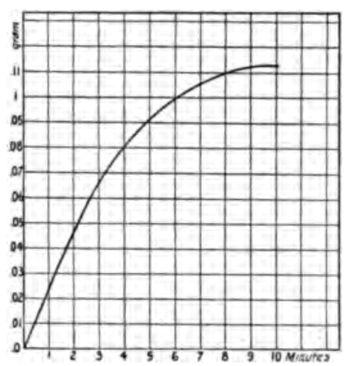
Cobalt.

Experiment.	Cobalt Present in Gram.	Sulphuric Acid Present in c.c.	Volume in c.c.	Current. Amperes.	Volts.	Revolutions of Anode Per Minute.	Time in Minutes.	Cobalt Found in Gram.	Error in Grams.
1	0.3525	.35	15	5	7	1250	15	0.3522	—0.0003
2	0.3525	.25	15	3	5	980	18	0.3524	—0.0001
3	0.3525	.25	15	4	6	600	14	0.3523	—0.0002
4	0.3525	.25	10	4	6	860	16	0.3530	+0.0005
5	0.3525	.5	10	4	6	1000	15	0.3530	+0.0005
6	0.3525	0	10	4	6	1240	16	0.3528	+0.0003
7	0.3525	.25	10	3	6	1200	10	0.3521	—0.0004
8	0.3525	.5	10	6	6	1200	10	0.3530	+0.0005
9	0.3525	.25	10	5	8	800	10	0.3522	—0.0003
10	0.3525	.25	10	3	8	1400	12	0.3523	—0.0002
11	0.3525	.5	10	6	5	800	11	0.3530	+0.0005
12	0.7050	.5	15	6	7	1200	30	0.7052	+0.0002
13	0.1762	.35	10	4	8	560	7	0.1762	——

Chromium.

A solution of chromium sulphate was electrolyzed with currents varying from 1 to 4 amperes and 7 to 12 volts and with a varying quantity of sulphuric acid. It was found by Myers that the addition of the acid was necessary, otherwise, there was a separation of the oxide of chromium throughout the liquid; but too much acid retards or entirely prevents the decomposition. When 10 drops (40 drops = 1 c.c.) were added and a current of 2.5 amperes and 6 volts applied one half hour was necessary to deposit 0.23 gram of chromium. With 0.5 c.c. of acid and a current of 5 amperes and 4 volts the solution at the end of 60 minutes did not appear to have lost its color. Experiments were then made to learn how

much chromium, if any, was deposited when the acid was present in large quantity. Thus, with a current of 4 amperes and 7 volts, solution containing 1 c.c. of acid, 0.05 gram of metal was precipitated in forty-five minutes; while with two cubic centimeters of acid and a current of 1 ampere and 4 volts the mercury showed no increase in weight after thirty minutes. The following results, obtained in the use of smaller amounts of acid, confirm this. By adding 10 drops of acid (= .25 c.c.) and employing a current of 4 amperes and 7 volts, the liquid became colorless in thirty minutes, but forty minutes were necessary for the complete removal of the metal. With the same quantity of acid, and a current of 5 amperes and 8 volts, the chromium was completely precipitated in thirty minutes. With five drops of acid and a current of 3 to 4.5 amperes and 8 volts, the solution became colorless in eleven minutes. It, therefore, seems that more than three drops of acid are sufficient to materially affect the rate of precipitation. More than two drops of acid must be present to prevent the separation of chromic oxide



CURVE 8. Chromium—3.5 Amperes, 11–10 volts.

which always took place with less than that amount of acid. The following conditions gave the most rapid determination: A volume of the solution, containing 0.1180 gram of chromium and three drops of sulphuric acid (40 drops = 1 c.c.), was electrolyzed with a current of 4 to 5 amperes and six volts, the speed of the anode being 400 revolutions per minute. In four minutes the solution was colorless and in six minutes the chromium was found to be completely deposited. The solution was siphoned off in the man-

ner previously described, but after the cell was removed anhydrous alcohol was poured in as quickly as possible and the operation repeated twice and followed by two washings with ether in order to prevent, if possible, oxidation of the chromium. Oxidation, if it occurred, was but slight, for the error never exceeded 0.0007 gram.

Curve 8 was constructed from the results given below:

In 2 minutes 0.048 gram of chromium was deposited.
" 4 " 0.085 " " " " "
" 6 " 0.1000 " " " " "
" 8 " 0.1105 " " " " "
" 9 " 0.1185 " " " " "
" 10 " 0.1185 " " " " "

Chromium.

Experiment.	Chromium Present in Gram.	Sulphuric Acid. 40 Drops = 1 c.c.	Volume in c.c.	Current Amperes.	Volts.	Revolutions of Anode per Minute.	Time in Minutes.	Chromium Found in Gram.	Error in Gram.
1	0.1180	5	10–15	3–4	7	280	15	0.1186	+0.0006
2	0.1180	3	10–15	2–4	11–9	280	15	0.1187	+0.0007
3	0.1180	3	10–15	1–3	9	640	20	0.1185	+0.0005
4	0.1180	3	8–15	1.5–3	10–8	220	15	0.1186	+0.0006
5	0.1180	3	10–15	1–3	11–9	520	20	0.1186	+0.0006
6	0.1180	3	5–15	1–2	11–9	640	17	0.1175	—0.0005
7	0.1180	3	5–15	2–4	9–8	480	15	0.1180	——
8	0.2360	3	5–15	2.5	10	520	50	0.2355	—0.0005
9	0.1180	5	5–15	3	7.5	400	15	0.1179	—0.0001
10	0.1180	3	7–15	4–5	8	640	6	0.1175	—0.0005
11	0.1180	3	7–15	3–4	10–9	640	10	0.1180	——
12	0.1180	7	7–15	3–4	10–8	200	13	0.1187	+0.0007
13	0.1180	3	5–15	3.5	8	640	11	0.1177	—0.0003
14	0.2360	4	5–15	3	12	640	35	0.2359	—0.0001
15	0.1180	3	5–15	3–4	10–8	320	11	0.1179	—0.0001
16	0.1180	3	5–15	3–4	10	540	11	0.1182	+0.0002

IRON.

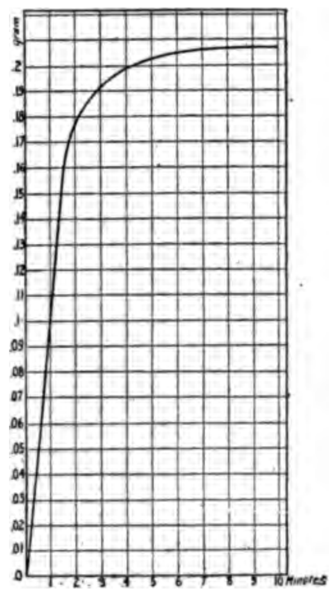
In experimenting with salts of this metal it was soon discovered that sulphuric acid in large amount retarded its precipitation. It was also noticed when higher currents were used that the solution became very hot and assumed a decidedly pink color,[1] which disappeared on the addition of cold water or when the cover glasses were removed, allowing the steam to escape rapidly and thus decreasing the pressure and consequently the temperature of the boiling solution. The color reappeared a few seconds after the cover glasses were replaced.

[1] Due to traces of manganese.

The conditions which gave the most satisfactory results were as follows:

Volume of solution 5 c.c. containing 0.275 gram of metallic iron, 3 drops of concentrated sulphuric acid and a current of 3 to 4 amperes and 7 volts. The rotation of the anode varied from 520–920 revolutions per minute. The iron was completely deposited in seven minutes. The following observations on rate of deposition were made under the conditions just given:

In 2 minutes 0.1760 gram of iron deposited.
" 4 " 0.2000 " " "
" 6 " 0.2050 " " "
" 8 " 0.2075 " " "



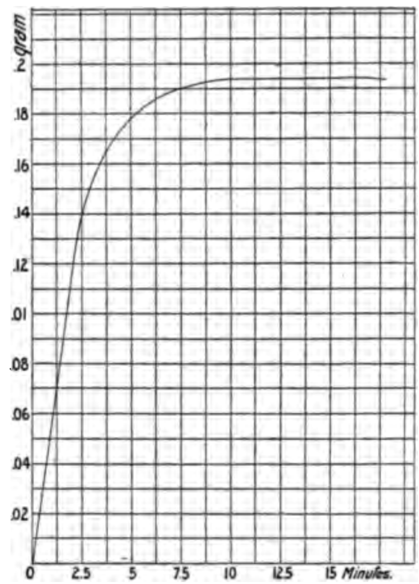
CURVE 9. Iron—3.5 Amperes, 7 volts.

In addition to the results just described a solution of ferrous sulphate containing 0.1945 gram of iron in 10 c.c. was used to get further working conditions. By using a current of 3.5 A. and 10–9 volts, with about 900 revolutions per minute of the anode, the total iron content was deposited in fifteen minutes. The residue from the decompositon cell when oxidized by nitric acid and tested with potassium sulphocyanide gave no color. The

Iron.

Experiment.	Iron Present in Gram.	Sulphuric Acid in Drops. 40 Drops =1 c.c.	Volume in c.c.	Current. Amperes.	Volts.	Revolutions of Anode per Minute.	Time in Minutes.	Iron Found in Gram.	Error in Gram.
1	0.2075	7	5	4–5	8–7	520	14	0.2072	—0.0003
2	0.2075	4	5–15	5–4	6.5–5	680	14	0.2078	+0.0003
3	0.2075	5	5–10	3.2–4	6.5	680	15	0.2077	—0.0003
4	0.2075	3	5	2–2.5	7–6	680	15	0.2073	—0.0002
5	0.2075	3	5	4	6–5	680	10	0.2080	+0.0005
6	0.2075	3	5	3–4.5	7–6	920	7	0.2078	+0.0003
7	0.2075	3	5	2–3	6	740	9	0.2076	+0.0001
8	0.2075	3	5	2–4	6.5–5.5	700	9	0.2076	+0.0001

experiments made to determine the rate of deposition with a lower current (1–2.5 amperes and 10–9 volts) while the other conditions



CURVE 10. Iron—1 to 2.5 Amperes, 10–9 volts.

remained as above, gave the following results which appear in Curve 10.

In	2.5	minutes	0.1141	gram	of	iron	was	deposited.
"	5	"	0.1787	"	"	"	"	"
"	7.5	"	0.1945	"	"	"	"	"
"	10	"	0.1950	"	"	"	"	"

When the residue was tested with potassium sulphocyanide no iron was detected. By the addition of 3 drops (40 drops = 1 c.c.) of sulphuric acid and using a higher current (3.5 amperes) in 10 minutes a faint reaction for iron was observed indicating that the acid has some retarding influence. In fifteen minutes under these conditions the iron had completely separated. By using a higher current 3 amperes and 9 volts under the same condition all the iron was deposited in ten minutes.

UNIVERSITY OF PENNSYLVANIA.

[Contribution from the John Harrison Laboratory of Chemistry.]

OBSERVATIONS ON COLUMBIUM AND TANTALUM.

BY EDGAR F. SMITH.

(*Read April 13, 1905.*)

In 1801 Hatchett, while studying minerals in the British Museum came upon a specimen from Haddam, Conn., which attracted his attention because of its rather high specific gravity and its brilliant black color. A portion of this material was given him for examination, with the result that he discovered in it a new metallic acid, to the metal of which he applied the name columbium. It was his earnest hope that he might obtain larger quantities of the American mineral in order to exhaustively study the new element, and it is of interest to remark that Hatchett fondly expected this material assistance from Thomas Peters Smith, a member of this Society and an enthusiast in chemical science, who on his return from England met an untimely death on shipboard.

In 1802 Ekeberg, of Sweden, while examining an unknown mineral, found that it contained a new metallic acid, to the metal of which acid he assigned the name tantalum, because "when placed in the midst of acids it is incapable of taking any of them up and saturating itself with them." Later, Wollaston (1809) strove to prove that columbium and tantalum were identical. In this he failed. The few reactions known even at that early day differentiated the new elements. About 1840, Heinrich Rose, in studying similar minerals, from other localities, came to the conclusion that the American mineral contained an element absolutely different from tantalum, and called it niobium. Subsequently, owing to his inability to account for the peculiar products which he got by chlorinating a mixture of the oxide of the new element and carbon, he asserted that, in addition to niobium, there was present pelopium (1846). Later (1853), however, he seems to have arrived at the opinion that niobic acid and pelopic acid were different oxides of niobium. The first he called niobic acid and the second hyponiobic acid. Hermann, also, contributed to the uncertainty which surrounded the two elements (columbium of Hat-

chett and tantalum of Ekeberg) in that he announced the existence of ilmenium; but it was not generally accepted by chemists. Hermann, however, persisted in his declaration that it occurred along with the other two elements to which reference has been made. v. Kobell believed that he had detected dianium in allied minerals. This unfortunate state of affairs prevailed until the early sixties, when Marignac, after a careful study of a number of minerals from various localities, announced the existence in them of but two elements — the columbium of Hatchett and the tantalum of Ekeberg — and added that the confusing reactions which had perhaps led Heinrich Rose — but most certainly, Hermann and von Kobell — astray were to be explained by the presence of titanium in all tantalites and columbites. It is only fair to say that Marignac never succeeded in obtaining titanium from any one of the minerals in which, according to him, it occurred, associated together with columbium and tantalum. Indeed, in his concluding paper on columbium he frankly acknowledged that the columbium compounds, which he used for the determination of the atomic weight of the metal, contained titanium, and that he knew of no method by which the latter could be separated from columbium. Marignac's conclusion was accepted by the chemists of the world as final.

When we come to examine the evidence which Marignac gives for the presence of titanium, we find that it is, practically: that the recrystallization of a double fluoride of columbium and potassium, supposed to contain titanium, gave rise, gradually, to a fraction which became more insoluble in water and the molecular weight of its acid oxide approached, within ten or more units, that required by titanic oxide. It is well to bear in mind that at no time did Marignac, whose ability and keen insight one would not for a moment question, give any tests which are ordinarily regarded as indicating titanium. He assumed it to be present on the evidence mentioned above, viz: the greater insolubility of the double fluoride and an approximate molecular weight corresponding to that required by titanic oxide. Ever since Marignac's day chemists the world over have tacitly accepted titanium as associated with columbium in columbites. They have also estimated its quantity by methods suggested from time to time. One of these methods is based on the color reaction which titanium salts give with hydrogen peroxide. Its intensity, compared with that shown

by a known amount of titanium, has been regarded by most analysts as entirely satisfactory. For the determination of the amount of titanium in columbium many methods have been proposed, but this is not the place to discuss them or their value.

As late as 1877, in the last paper published by Hermann, he announced the element neptunium and claimed to have obtained it from the acid mother liquors remaining after tantalum potassium fluoride, ilmenium potassium fluoride and columbium potassium fluoride had been crystallized out. The particular mineral in which he observed it was a columbite from Haddam, Conn.; in other words, the same mineral in which columbium had been originally discovered by Hatchett.

The existence of neptunium has never been contradicted. This is probably because the majority of chemists thought that the verdict in regard to the constitution of tantalites and columbites had been given by Marignac, and that the numerous, unusual reactions of the metallic acids contained in those minerals, noted and commented upon at various times by Heinrich Rose, von Kobell, Blomstrand and Hermann, were all due to the contaminating influence of titanium.

The two elements, columbium and tantalum, in their derivatives, have received comparatively little attention within the last quarter of a century, although at intervals attempts have been made to clear up the mystery which, in a certain sense, surrounds them. In this laboratory, several investigations upon derivatives of them have been made. These being not wholly satisfactory, about three years ago, 50 lbs. of columbite from South Dakota and 25 lbs. from Haddam, Conn., were worked up, with a view of getting an abundant supply of starting-out material; with the view, also, of studying anew the various derivatives of both columbium and tantalum. In the year 1903–1904, Dr. R. D. Hall devoted, in this laboratory, much time and labor to the double fluorides of tantalum and columbium. He made a comparative study of the reactions of the same with the reactions of titanium. His results have been published, but from an examination of them it will be observed that he was not able to find any tests, while using the double fluorides, which differentiated titanium from columbium so thoroughly that he could expect to obtain a complete separation of these two most interesting elements. It is true that he was able, by precipi-

tating potassium columbium fluoride incompletely with ammonia, to get a columbium oxide, which apparently gave no response to the hydrogen peroxide test upon its application, or to the reagent called chromotropic acid. Hence he inferred that he had eliminated the titanium from the columbium. More recent work with large quantities of material has demonstrated that in the latter cases it was impossible to entirely remove the metallic acid which gave the color tests. It was further found that by the action of sulphur monochloride upon the oxides of columbium and titanium, corresponding chlorides were produced; but again, it proved impossible to wholly expel the titanium from the columbium by this process, notwithstanding titanium chloride is an exceedingly volatile liquid and columbium chloride a solid, crystalline body.

In the present year, we have, in this laboratory, prepared large quantities of the double fluoride of tantalum and potassium, and found no difficulty whatsoever in eliminating from it every trace of what was supposed to be the titanium double fluoride.

Having thus, at our disposal, such generous amounts of pure tantalic oxide, free from columbic oxide, in short, really pure tantalic oxide, it was determined to make a new study of the double fluorides of tantalum with the alkali metals and organic bases. This was undertaken in order to discover, if possible, why Dr. Pennington, when working in this laboratory in 1895, obtained double fluorides of tantalum and columbium with cæsium, which showed these unusual formulas: $15CsF.\ TaF_5$ and $7CsF.\ CbF_5$, which varied so widely from those generally followed by the double fluorides of tantalum and columbium, and were not in accord with the law proposed for double halides (*Amer. Chem. Jour.*, v. 291).

At the outstart it was thought that this re-investigation of the double fluorides would prove to be an easy and simple matter. But it was not long until it was seen that the discordant results of Dr. Pennington were probably due to the fact that there was more than one cæsium tantalum fluoride. Indeed, the latest work done in this laboratory, by Mr. C. W. Balke, proves that there are two cæsium tantalum fluorides, two rubidium tantalum fluorides, two sodium tantalum fluorides, two ammonium tantalum fluorides, and so forth, of these ratios:

$TaF_5.CsF$	$2TaF_5.3RbF$
$TaF_5.2CsF$	$TaF_5.2NaF$
$TaF_5.2NH_4F$	$TaF_5.3NaF$
$TaF_5.3NH_4F$	$TaF_5.2KF$

The existence of several such double fluorides with each of the alkali metals naturally raises the question whether these salts ought to be used for the determination of the atomic weight of tantalum, inasmuch as each salt is likely to be contaminated with smaller or larger quantities of the other, depending upon the condition or the care with which they are prepared. Marignac used potassium tantalum fluoride and ammonium tantalum fluoride in his re-determination of the atomic weight of tantalum. It would seem, from the study of the salts just mentioned, that even this skilled and careful analyst could not have been sure that he had a definite, homogeneous body in the determinations which he made. Of course, if there was even a slight amount of a second salt in the salt used for the atomic weight work, it would naturally vitiate the final result. Of all the double fluorides of the alkali metals and bases with tantalum which have thus far been studied by Mr. Balke, that of sodium and tantalum, of the ratio 3 to 2, seems to be the one having some definite and most stable characteristics. We hope to re-determine the atomic weight of tantalum, but it is not probable that we shall use any one of the double fluorides, of which mention has been made, although they appeal strongly because of the ease with which they can be crystallized. The uncertainty, however, as to whether they are really absolutely of one definite ratio every time that they are crystallized is uncertain. Hence they had better be abandoned in atomic weight determinations.

The question may also be asked, may not the double fluorides of columbium with the alkali metals, which have been used for atomic weight purposes, been contaminated with salts of varying ratios? This point will receive attention.

Turning again to columbium, it seems proper to record that having eliminated the tantalum completely from a mixture of oxides obtained from Haddam columbite, the remaining potassium columbium oxy-fluoride was crystallized a number of times from water and also from solutions containing much hydrofluoric acid. This procedure finally gave a mother liquor that was decidedly acid. A metallic acid remained in this mother liquor. According to Her-

mann, in his communication of 1877, this acid should be neptunic acid. Therefore, the acid mother liquor was treated as directed by Hermann; namely, it was evaporated, the residue was dissolved in water and the boiling solution precipitated with an excess of caustic soda. The precipitate, after the liquid had become cold, was filtered out, pressed thoroughly from adherent water and then boiled with 25 times its own weight of pure water. Everything dissolved. The solution was perfectly clear. On cooling, there separated from it the beautiful needle-like crystals of sodium columbate. According to Hermann, the precipitate which was collected, pressed out and then boiled with water, should, if neptunium were present, have left a slimy mass, insoluble in water. This, Hermann said, was sodium neptunate. It should be observed that our experiments were made with the final acid liquors obtained from the double fluorides present in columbite from Haddam; further, that we proceeded in strict accordance with the directions of Hermann and having done all this, did not obtain a gelatinous mass which might have been sodium neptunate. In Hermann's communication, to which reference has been made so frequently, he lays great stress on the fact that the distinguishing reaction of neptunium is the beautiful golden yellow color which sodium neptunate imparts to a salt of phosphorus bead in the *reducing flame*. It is needless to add that we tried on different occasions to find neptunium, according to the directions of Hermann; but our search was fruitless. On one occasion, however, we obtained a mass, not great in amount, which, in the inner blow-pipe flame, did impart a yellow color to the salt of phosphorus bead, but more careful examination of this residue demonstrated that it contained tantalum, iron and some columbium. The intense golden yellow color, which was so strongly emphasized by Herman, we could not get; so that it is very probable that neptunium, like ilmenium and the other metals announced from time to time as present with columbium and tantalum must really be placed in the list of defunct elements. It has not been our wish to bury this candidate for elemental honors. Indeed, we would have been only too glad to have found the evidences of its existence and to have confirmed the observation of that earnest and sincere student of chemical science, who, in his tireless labors, frequently felt confident that he had fallen upon the cause of the varying results observed with columbium and tantalum.

In this connection it may be added that, having freed the tantalum and columbium oxides as thoroughly as possible from ordinary contaminations, the problem of removing tungsten and tin confronted us. After much experimentation, we found that the certainty of the removal of these impurities could only be had by fusing the tantalum and columbium oxides with sodium carbonate and sulphur. It is true that small quantities of tantalum and columbium will be lost, being carried along with the tungsten and tin, but as we were seeking a method of purification and not a separation, we adopted this course. It is the one which was pursued by Heinrich Rose. Our own experience leads us to say that the removal of tungsten and tin from columbium and tantalum oxides cannot be realized by digestion with ammonium sulphide. Indeed, not only did we find the fusion with the sodium carbonate and sulphur necessary, but that working in large quantities of material, as in our case, two and three refusions with these reagents were found necessary. Another point of interest in connection with the purification of the tantalum and columbium oxides may be mentioned. It has frequently been said that in crystallizing out the double fluorides of these metals, if titanium be present with them, it will be found in the potassium tantalum fluoride. We have encountered no difficulty in getting potassium tantalum fluoride perfectly free from what is supposed to be titanium by one or two crystallizations. It has been assumed that as potassium titanium fluoride is rather insoluble in water, it would naturally go with potassium tantalum fluoride. This, however, seems to be an incorrect observation. It masses with the columbium potassium fluoride; at least the element which gives the yellow color with hydrogen peroxide, or a rose red with chromotropic acid is always found associated with the columbium. How to free the columbium from titanic acid we do not know. We are in precisely the same position as that of Marignac, notwithstanding we have probably made greater efforts than he to remove it from the columbium. It is this point in our investigation upon which we have been continuously at work for the last year. We have tried fractional precipitation with ammonia water, fractional crystallization of the double fluorides, fractional chlorination of the oxides in the presence of carbon and the action of numerous organic bases, without finding any way of effecting a separation. Indeed, the separation of columbium and titanium is a problem

which the analyst has not solved up to the present. As remarked, it has received and is receiving our daily attention. Once having achieved this result and having definitely determined the character of the color-giving metallic acid, or proved it to be titanium, without any further doubt, we then hope to subject the purified columbic oxide to a searching review in all its derivatives, just as we are now doing with the compounds of tantalum. In anticipation, it may be said that there are some most interesting complexes of tungstic acid with tantalic oxide and also of tungstic acid and columbic acid. These are under study at present. These complexes, also, have brought analytical problems that are most puzzling. Yet our progress with them leads us to hope for a separation and a satisfactory solution of the same.

Some attention has likewise been given to per-tantalates and per-columbates. It would not be the least surprising to find these derivatives answering admirably for atomic weight work.

UNIVERSITY OF PENNSYLVANIA.

ENQUIRY INTO THE PRESSURE AND RAINFALL CONDITIONS OF THE TRADES-MONSOON AREA.

BY W. L. DALLAS.

(Read April 14, 1905.)

In 1900 the writer undertook the discussion of the seven monsoon seasons 1893 to 1899 and showed that during those seven years there occurred a series of oscillations of pressure and that between these oscillations and the monsoon rainfall over India there existed a very distinct and marked relationship. The data used in this discussion consisted of the mean monthly and seasonal variations of pressure over India, derived from all the stations employed in the Daily Weather Report of the Meteorological Department, and the mean monthly and seasonal variations of pressure over the Equatorial Belt and the Arabian Sea as given by the pressure observations recorded (1) at the Seychelles, Zanzibar and Mauritius and (2) on board ships traversing the Arabian Sea and the South-east Trades Region.

The relationship as established for those seven monsoon seasons was as follows: (1) The Indian monsoon rainfall was in defect during the rising portions of these pressure oscillations and in excess during the falling portions while the amount of the rainfall variation agreed directly with the rapidity of the pressure changes. (2) The pressure oscillations exhibited a periodicity of about four years.

It was carefully pointed out at the time that the discussion dealt solely with the seven years under review so that, though the agreement there disclosed was exact and clear, it was obvious that a much longer series of observations would be required before it would be safe to assert that the period of the oscillations and the relationship between the pressure oscillations and the rainfall, as disclosed in the discussions, could be accepted as having a general application. As a matter of fact, before the publication of the paper, it had already become apparent that the relationship had not been maintained, while a simple examination of the existing rainfall data of India showed that there does not obtain any simple

four-year cycle in the Indian rainfall. The author believes that these four-year oscillations form the basis of the weather changes over the Indian monsoon area, though there occur at times violent or spasmodic interruptions, the cause of which is not as yet apparent, and that these interruptions are the cause of the great irregularities in the course of the pressure cycle and in the occurrence of the variations of rainfall. Since the history of these seven monsoon seasons was written, Professor Bigelow's "Contributions to Cosmical Meteorology"[1] has appeared. In it the following paragraph occurs:

"The increase of solar magnetic intensity is synchronous with a diminution of temperature but with an increase of pressure and this function persists throughout every phase of the research. In spite of some irregularity there is a distinct conformity in the general sweep of these curves and also in the tendency to describe crests during the same years. Indeed the occurrence of four subordinate crests in the 11-year periods suggests strongly that a $2\frac{3}{4}$-year period is superposed upon the long sweep of that period curve. Apparently this minor period is the basis of the seasonal variations of the weather conditions of the U. S. A. more than anything else, so that in long range forecasting this period must be very carefully considered."

It will be noticed that the period of these minor oscillations as then determined by Professor Bigelow was $2\frac{3}{4}$ years for the United States. Subsequently Professor Bigelow produced his "Report on the Barometry of the United States" and from the complete data there employed he obtained an eight-year cycle of pressure which is a simple multiple of the four year cycle determined for the Indian Monsoon Area. Professor Bigelow's researches terminate with the year 1899 but where they overlap the Indian series of observations the principal characteristics of the two series agree. Thus Professor Bigelow obtains a maximum in 1896 and a minimum in 1898 with pressure rising again to a maximum through 1899. In the Indian equatorial area the period is approximately four years, and the writer agrees in believing that these minor oscillations of pressure are mainly influential in determining the seasonal variations of weather. On this point it appears probable that the ex-

[1] See Monthly Weather Review, July, 1902, and especially, Weather Bureau Bulletin, No. 21, pp. 125-6, Washington, 1898.

perience of the Indian area will be found to correspond with that of the United States. It must however be born in mind that the investigation is one of extreme complexity and that superposed on the four-year or minor oscillation there are great irregularities which cannot now be explained but which at times completely upset the regular course of the cycle. Notwithstanding these irregularities and interruptions it appeared to the writer that in face of the remarkable agreement between the pressure oscillations and the rainfall during the years 1893 to 1899 it was worth while to continue the discussion in a more exact and detailed manner so as to determine (1) over what area the pressure oscillations extended (2) how far they agreed in amplitude and in time throughout the affected area and (3) what relation the rainfall of the whole monsoon area bore to the pressure oscillations.

The author has collected and discussed a large amount of material and has arrived at certain conclusions which he regards as tentative and far from satisfying. He feels doubtful if the observations would fulfil the requirements which Professor Schuster laid down as a means of estimating the reality of the periodicity, but the investigation has brought out certain relationships which appear at least worthy of record.

The tentative conclusions arrived at are as follows:

(1) That over the trades monsoon area—and most markedly so over the equatorial belt—there occur four-year oscillations of pressure; (2) that during the rising portions of these oscillations the *general* rainfall of the trades monsoon area is below, and during the falling portions is above the average, with a well-marked minimum of rainfall in the first year of the cycle and a well-marked maximum of rainfall in the third year; (3) that from the Antarctic or extreme southern regions there emanate at irregular intervals rays or streamers of varying extent and intensity which occasion increased atmospheric pressure over the affected area; (4) these rays or streamers are apparently not in the least in the nature of waves, as they affect large areas practically simultaneously and continue for considerable periods; (5) when these rays or streamers are frequent and extensive, as in portions of the years 1899 and 1900, pressure ranges largely above the normal, but exhibits large oscillations or fluctuations; when on the contrary they are absent as in portions of the years 1898–1899 pressure is low and the oscil-

lation's small; (6) these variations are superposed on the four-year cycle of the tropical belt, and are spasmodic, occurring at irregular intervals over irregular areas so that their influence occasions irregular variations of rainfall and irregularities in the pressure cycles.

There appears to be no satisfactory explanation either of the four-year cycle of pressure over the trades monsoon area or of the irregular spasmodic disturbances of pressure referred to above. With regard to the cycles it is possible that compensatory actions are at work, so that when atmospheric pressure increases in one part of the world it decreases in another, though the evidence of the barometry of the United States is opposed to this and rather suggests that the principal secular variations of pressure are of a uniform character over the whole globe. It is impossible to believe that the variations of pressure are a *result* of variations of rainfall. For one thing, the variations are as marked in a dry area like Aden as in a wet area like Bombay, and for another, the evidence, so far as it can be sifted, shows that the variations of pressure *precede* the variations of rainfall. Thus the increase of pressure which culminated in the large excess of pressure in the months of July, August and September, 1899, commenced in February of that year, thus *preceding* by some months and not *succeeding* the scanty rainfall of that season.

The memoir contains all the figures and data on which the enquiry is founded. Some of the observed changes are at present quite inexplicable, but the observations are given as recorded so that though the author has not succeeded in obtaining any conclusive results, it may be possible for other students of meteorology with more available leisure to work them into a more harmonious scheme.

In order to undertake this detailed examination the employment of pressure or rainfall means of large areas has been abandoned, and instead the actual monthly pressures and their variations for certain selected stations, which it is believed represent fairly adequately the whole monsoon area, have been used. The list of stations includes: Batavia, Calcutta, Bombay, Aden, Cairo, Madras, Colombo, Seychelles, Zanzibar, Mauritius, Durban and Perth, while in addition the marine observations of the Arabian sea and the Equatorial belt have been utilized to obtain averages for those

areas, mainly with the object of determining whether, in the case of these pressure oscillations, there occurs any horizontal translation in the pressure changes or whether they occur simultaneously throughout the whole area.

Numerous tables and figures are given in the memoir to assist in the discussion of the observations.

METEOROLOGICAL OFFICE,
INDIA.

THE RELATION BETWEEN THE ECONOMIC DEPTH OF A BRIDGE TRUSS AND THE DEPTH THAT GIVES GREATEST STIFFNESS.

BY MANSFIELD MERRIMAN.

(*Read April 14, 1905.*)

The fact that there is a certain depth for a bridge truss which renders the quantity of material a minimum has long been known, and the marked increase in the depth of bridge trusses which has occurred during the past quarter of a century is due to the efforts of manufacturers to use the least possible amount of material. It has generally been supposed that the vertical deflection of a bridge under a moving load decreases with the depth, and this is true for plate girders. For a truss, however, investigations made by the author show that the least deflection and hence the greatest stiffness increases up to a certain limit, as the depth increases, and then decreases, so that there is a depth which gives the truss its greatest vertical stiffness.

The following are the results obtained by the author for the type known as the deck Pratt truss. Let l be the span, d the depth, p the panel length, and n the number of panels, so that $l = np$. The economic depth was obtained by forming an algebraic expression for the amount of material in the truss in terms of its dimensions, given loads and allowable unit-stresses, and then finding the value of d/p which renders that expression a minimum. There were found,

for n	=	4	8	12	20	30
d/p	=	1.29	1.73	2.08	2.65	3.21
d/l	=	0.32	0.22	0.17	0.13	0.11

which shows that d/p increases with length of span while d/l decreases with length of span. To determine the depth that gives greatest stiffness, an algebraic expression for the stored energy in the truss due to the deformation of its members was formed and this equated to the deflection due to the given loads. Then the values of d/p that render this expression a minimum were deduced for different values of n, as follows:

for n =	4	8	12	20	30
d/p =	1.29	1.63	1.92	2.38	2.85
d/l =	0.32	0.20	0.16	0.12	0.09

which give laws similar to those of the economic depth, and which show that the depth which gives the greatest stiffness is slightly less than the economic depth. It hence appears that no additional stiffness can be imparted to a bridge by giving to the truss a depth greater than the economic depth.

April, 1905.

ON THE USE OF THE FALLING PLATE OSCILLOGRAPH AS A PHASE METER.

BY WILLIAM McCLELLAN,

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(*Read April 14, 1905.*)

The wave form of a periodic quantity is the curve which shows the magnitude of the quantity for each instant of time. It is always interesting and careful examination reveals relations that could hardly be discovered in any other way. In alternating current calculations, however, little can be done until the wave form is known accurately. There are two general methods in use, by which it may be determined—the *point to point method* and the *oscillograph* method. In the first, the quantity is measured by a meter, through which the circuit is closed, by a revolving contact-maker, for an instant at any part of the wave for which it may be set. The meter then indicates the value of the quantity at that particular point only. By taking such readings at various points in the cycle, the whole wave may be plotted. As this process is somewhat laborious, various instruments, called *wave tracers*, have been designed to facilitate the operation. In the *Rosa curve tracer* a double potentiometer is used. The operator fixes his eye on the galvanometer, and produces balance by means of a small crank, which turns the cylinder carrying the potentiometer wire. When this occurs, a second lever is pulled, which automatically prints a point of the curve on a paper fixed in the proper position, and also turns the contact-maker to the next position.

Either of the foregoing methods requires considerable time to plot a whole curve. The successive points are obtained from different waves. For example, a good operator can get a curve in five minutes if the instrument is in order. If he is working on a sixty-cycle circuit, he has obtained his curve from 18,000 successive waves. It will be a true curve, therefore, if he has kept his conditions absolutely constant in the interval. This is always troublesome to do, but particularly so in commercial work where the operator seldom has control of the generator. To avoid this

difficulty, the oscillograph has been devised, by which it is possible to obtain the form of a single wave, or a number of successive waves.

The oscillograph is essentially a galvanometer of very short period. The one used in this work as shown in Fig. 1 is of the moving coil type, made under the Duddell patents. The field is

FIG. 1.

supplied by an electromagnet, the coils of which are wound in several sections, so that different voltages may be used for the exciting current. The normal current nearly saturates the core, so that slight changes in the value of the current do not cause appreciable changes in the strength of the field. The coil consists of an inverted U with the ends rigidly fastened at the bottom by a rubber block, and connections made to the binding posts. The upper loop is threaded over a small pulley, to which is fastened the spring by means of which the tension is applied to the strips. There are two distinct loops, thus permitting the taking of two curves simul-

taneously. The free period is approximately one ten-thousandth of a second, undamped. There are three mirrors, one fastened on each coil, and one fixed in the center, to give a zero line. The maximum current used is about one tenth ampere.

To obtain a curve, it is necessary to provide uniform motion perpendicular to the motion of the mirrors. In this instrument it is accomplished by means of a falling photographic plate. This

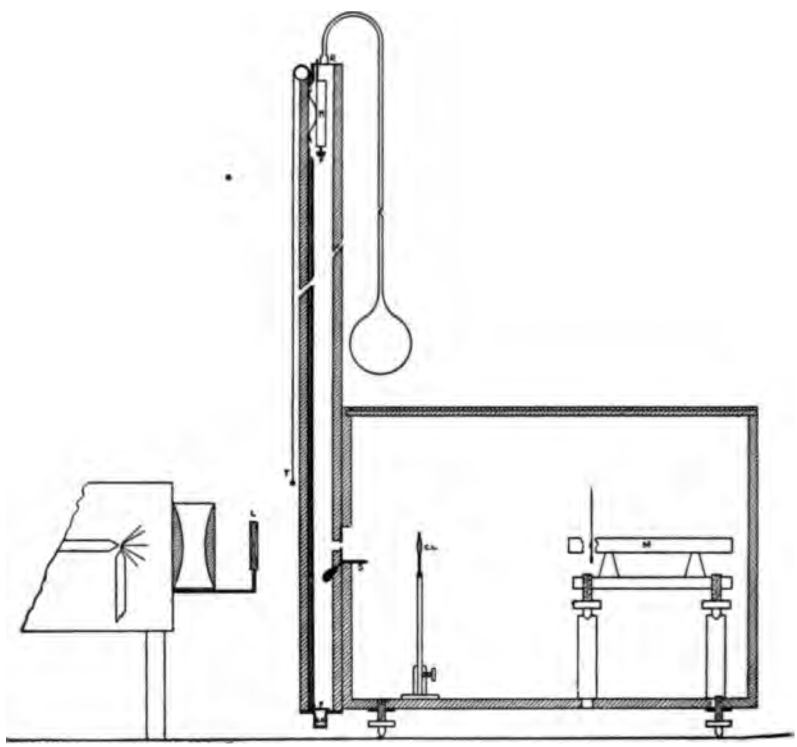

FIG. 2.

motion is uniformly accelerated, but the error in the length of the plate is very slight, though measurable. The error amounts sometimes to about a half per cent. of the wave length. The arrangement can be understood from Fig. 2. The galvanometer *M* is placed in a camera as shown. This is provided with a slit in the end, through which parallel light is sent. The ribbon of light

falls on the three mirrors of the galvanometer, and is reflected to the cylindrical lens *CL*. This renders the parallel ribbon of light a point. The lens is focussed so that this point is in the plane of the photographic plate. The chute through which the plane is dropped is about ninety-five centimeters long, giving the plate a speed which allows the record of one twenty-five cycle wave on a four by five plate. Light enters the chute through a slit which is provided with the hand shutter *S*. The shutter is open when the plate is dropping, but is closed before the plate is pulled back to the top so that the slide may be inserted. This prevents any possibility of fogging. The plate is carried in an ordinary wooden four by five plate holder. This in turn is held by a light wooden carriage *H*, which is provided with springs on the sides and back. These are adjusted so that they just bear on the surfaces of the chute, thus providing a very steady motion of the plate during the fall. The springs also serve the purpose of holding the front of the plate holder tight against the chute. The plate is started by means of a bulb release *R*, and is stopped by an airdash pot *D.P.* The bottom of the carriage is provided with a leather packed brass piston which fits the cup. Light is provided by a powerful 25-ampere arc light, which has the usual condensers. In addition, to get a proper parallel beam, the concave lens *L* is provided. The whole camera is provided with leveling screws, in addition to those for the galvanometer. This is necessary, since the chute must be vertical. The low potential currents used in this work were brought to the galvanometer by lamp cords, which passed through corks in the side of the box. For convenience in lifting the plate holder and carriage the sliding bracket *F* is provided. This is raised by the knob and string *T*, lifting the carriage until it catches in the release apparatus. The bracket then drops to the bottom of the box. It is held in place by a rod, on which it slides. For access to the camera, the whole top of the box is arranged to slide in a light tight groove.

To adjust the apparatus for a curve the chute is first made perpendicular by the outside levelling screws. Then the galvanometer is levelled with its own screws. The arc light is then adjusted so that a strong beam of closely approximate parallel light falls on the mirrors. The galvanometer is then adjusted, if need be, so that the images pass through the center of the slit. Since

the mirrors have practically the same horizontal axis, though they are not in the same vertical plane, necessarily, the spots when focussed on the plate will be in the same horizontal line. They must be adjusted, however, until they have the same vertical axis when not vibrating. This adjustment, as well as the focussing, is done by means of a small glass cylinder with a ground glass end. This is entered through the back of the chute, and is of such a length that the ground glass is in the plane of the falling plate. The focussing is finished and the cylinder removed. After a time, that is with some experience, the focussing can be done from the front of the box. There is no adjustment for the verticality of the mirrors. The coils may be twisted, however, so that they may be brought to various horizontal positions by adjusting screws on the side of the standard.

The double oscillograph permits the simultaneous taking of two independent curves. Since the loops are so fine, and the area of the field so large, comparatively, the loops move in a constant field. The amplitude of the wave is therefore proportional to the maximum value of the current passing through the loops. This will be so only when the damping is critical, that is, sufficient to prevent running past the static position for the same current, and not too much to prevent the loop reaching its static position. A proper adjustment of a non-inductive resistance in series with the loops would make the deflection a definite fraction of an ampere per millimeter. One of the suggested uses to which the double instrument may be put is to obtain the current and potential difference curves for the same piece of apparatus. That this cannot be done, at least exactly, will be apparent from a little study of the conditions. The problem is similar to the wattmeter problem, in which there is always a slight error, due to either the current or the E.M.F. required for one of the coils. The inference is also frequently suggested that the difference in phase, as indicated by the record of the two curves, is the true difference of phase between the quantities. That this is never true, and seldom approximately so, will be apparent from the following discussion :

The simplest method of putting the oscillograph in circuit is shown in Fig. 3. L is the apparatus for which the current and E.M.F. curves are to be determined. O_1 and O_2 are the two loops of the oscillograph joined in circuit as shown. Usually it would be

necessary to have a non-inductive resistance in series with each loop to cut down the current to a proper value. A non-inductive shunt is also frequently used with the current loop. Fig. 4 pro-

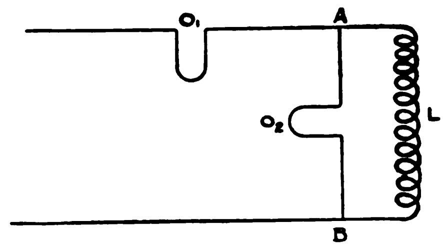

FIG. 3.

vides an analysis of the quantities involved. Let E be the potential difference between A and B. Lagging behind this at an angle α is the current in $L(i)_3$. Also lagging behind E at an angle δ is the current in $O_2(i_2)$. But the current through O_1 is the vector sum of i_2 and i_3 or i_1. Now the angle, or rather the space on the

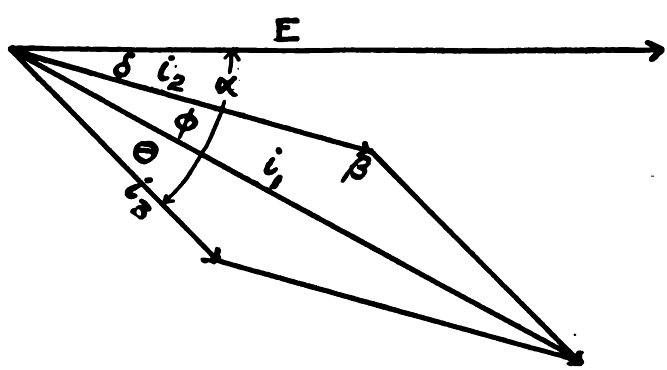

FIG. 4.

plate equivalent to the angle, is of course the angle of phase between i_1 and i_2 and not between E and i_3, as is frequently inferred. It may approach in certain cases, but it is never the true value. The angle desired, that is α, is given by the relation

$$\alpha = \delta + \varphi + \theta. \qquad (1)$$

To obtain it we have the following derivation:

$$\frac{i_1}{i_2} = r = \frac{\sin\beta}{\sin\theta} = \frac{\sin(\varphi+\theta)}{\sin\theta},$$

$$r = \sin\varphi\cot\theta - \cos\varphi,$$

$$\cot\theta = \frac{r}{\sin\varphi} - \cot\varphi,$$

$$\therefore\ \alpha = \cot^{-1}\left(\frac{r}{\sin\varphi} - \cot\varphi\right) + \varphi + \delta. \qquad (2)$$

Before we can determine α, therefore, we have to determine δ.

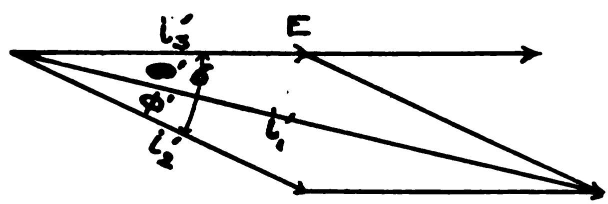

FIG. 5.

The latter may be obtained by putting a non-inductive resistance in place of L. This is shown in Fig. 5, from which as before

$$\delta = \cot^{-1}\left(\frac{r'}{\sin\varphi'} - \cot\varphi'\right) + \varphi', \qquad (3)$$

where

$$r' = \frac{i_1'}{i_2'}.$$

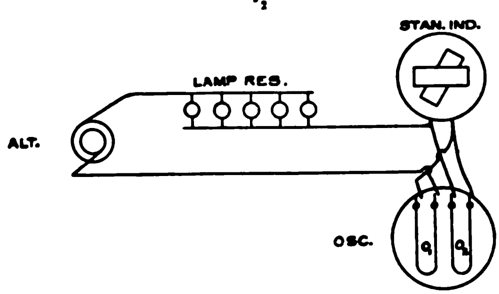

FIG. 6.

To illustrate, and provide a test, arrangements were made as in Fig. 6. An alternator which was under the control of the oper-

ator, so that its speed could be maintained constant, was connected through a lamp resistance, a variable standard of inductance, and the loop O_1, in series. The other loop was connected across the inductance. The resistance of the standard of inductance was 9.89 ohms in all positions. The angle of lag for any given position was therefore easily calculated. Moreover, as the resistance of an oscillograph loop with its fuse, is also about ten ohms, quite a difference between a and φ could be expected. Now we have to determine r, φ, and δ, in order to determine a. The procedure was as follows. With the inductance set to some definite value, L, a plate was taken. Such a plate is shown by Fig. 7. With

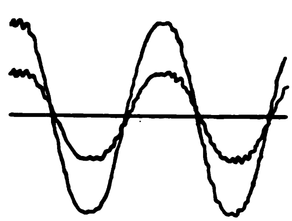

FIG. 7.

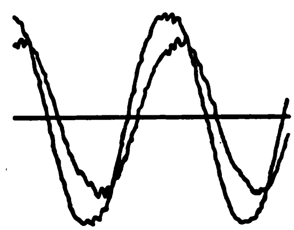

FIG. 8.

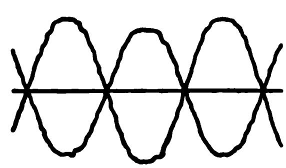

FIG. 9.

the standard set to zero another plate was taken. This is shown in Fig. 8. Now to obtain the ratio r, we have to measure the ratio of the amplitudes of the two waves. As these waves are obtained from two different loops, it will be necessary to obtain the ratio of the galvanometer constants of the two loops. A third plate was taken with the two loops connected in series, and one current passing through both. For accuracy in measurement, the loops were connected oppositely, so that an apparent phase difference of 180 degrees results. This is shown in Fig. 9. The following measurements are then made. $C =$ the ratio of galvanometer constants of the two obtained from ratio of amplitudes in Fig. 9.

$r = i_1/i_2$ obtained from ratio of amplitudes in Fig. 7.

λ_ϕ and $\lambda_{\phi'}$ wave-lengths obtained from Figs. 7 and 8 respectively.

l_ϕ and $l_{\phi'}$ phase displacement, obtained from Figs. 7 and 8 respectively r obtained from ratio of amplitudes in Fig. 7.

During the taking of each plate the value of the frequency must be observed.

R = resistance of the standard of inductance. We then have the following:

$$\varphi = \frac{l_\phi}{\lambda_\phi} 360, \quad \varphi' = \frac{l_{\phi'}}{\lambda_{\phi'}} 360.$$

By substituting φ' and r' in (3) we get δ. By substituting φ, δ and r in (2) we get α. The true value of α is given by the relation

$$\alpha = \tan^{-1} \frac{L\omega}{R}.$$

Values for α as obtained from five different sets of plates are given. A calculation on the first plate showed that δ was practically equal to φ', so that (3) was not used.

No.	C	λ_ϕ	l_ϕ	r	$\lambda_{\phi'}$	$l_{\phi'}$	δ	ϕ degrees.	θ degrees.	α degrees.	L henrys.	$\tan^{-1} \frac{L\omega}{R}$ degrees.
1	1.14	1.74	.11	1.36	1.76	.025	5.1°	22.8	32.3	59	.040	56.8
2	1.15	1.79	.10	1.55	1.73	.025	5.2	20.0	23.5	47	.030	48.8
3	1.12	1.98	.125	1.36	2.02	.020	3.6	22.3	31.8	59	.040	56.8
4	1.13	2.17	.13	1.36	2.11	.025	4.3	21.6	30.5	57	.040	56.8
5	1.12	2.08	.13	1.37	2.12	.025	4.2	22.3	31.8	59	.040	56.8
	1.13						4.5°					

$R = 9.89 \qquad \omega = 377$

It is evident, that in the simplest application of the oscillograph, a mere inspection of the plate is not sufficient to obtain the true difference of phase. The general case is much more complex. This is represented by the diagram of connections in Fig. 10, and the vector diagram in Fig. 11. It is necessary to introduce a series non-inductive resistence in circuit with O_2, and a shunt on O_1, in order to bring the current to a proper size. The letters have the same significance as before, and in addition s is the resistance of the shunt, R' is the series resistance, i_t is the total current, and i_s is the current in the shunt. As before, the angle (Ei_2) is the quantity desired. Now a plate obtained with the connections arranged as in Fig. 10, would give us i_1, i_2, and the angle (i_1i_2),

granting that the loops have been calibrated so that current values may be measured by them. It is evident that if the multiplying power of the shunt for direct currents is known, i_t can be obtained from i_1 without serious error. Also since s is non-inductive, the angle $(i_1 i_3)$ can be known from a plate taken similarly to Fig. 8. Then the angle $(i_1 i_t)$ can be calculated, and subtracted from the angle $(i_1 i_2)$ leaving the angle $(i_2 i_t)$. Having the latter angle, with i_t and i_2, $(i_t i_3)$ can be calculated, and added to $(i_t i_2)$, and (Ei), which is known as before, thus giving Ei_3, which is the desired angle.

The writer has not worked the latter discussion out for two reasons. First, the errors of measurement on a photographic plate

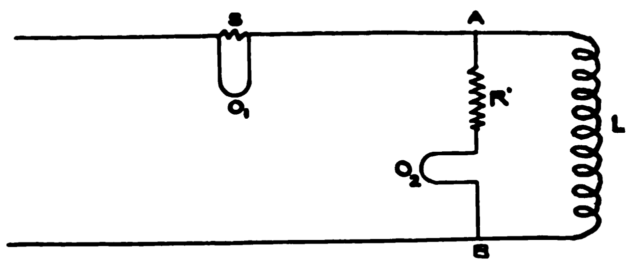

FIG. 10.

would not permit of any accurate results since in any case the angles are small. Second, in the large majority of cases, the multiplying power of the shunt is so large, that the currents i_1 and i are in the same phase, so far as could be measured. Also the resistance in the O_2 circuit so large that E and i are in the same phase. Therefore the angle desired can be obtained exactly as δ was in the preceding discussion, with the introduction of the multiplying power of the shunt. The use of ammeters in some of the circuits would greatly facilitate matters in many cases.

The above discussion shows that, with the oscillograph, the phase angle can be calculated. In no case can it be obtained by a simple measurement on a single plate. Owing to the thickness of the lines traced by the moving spot, measurements cannot be made closer than a quarter of a millimeter, so that a long curve must be obtained if any accuracy is to be attained, especially with small differences of phase. While the double oscillograph could not be recommended in any way as a phase meter, yet it does permit an ap-

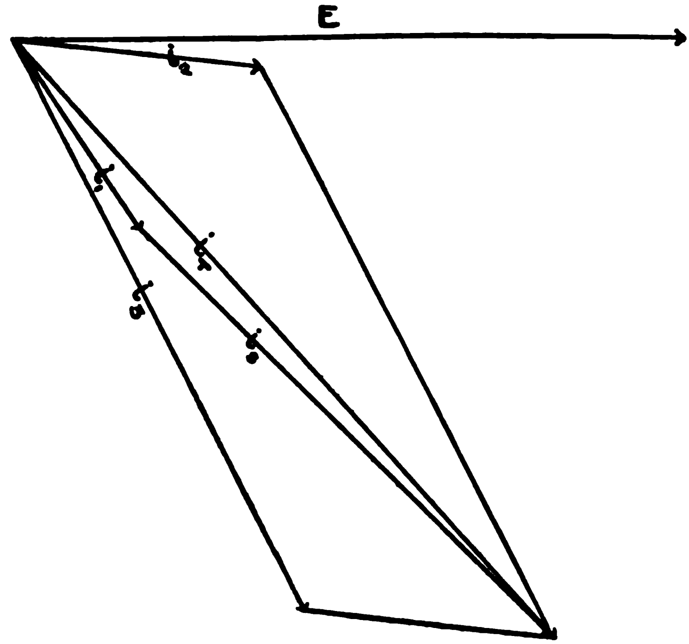

FIG. 11.

proximate value of this quantity being obtained. In most of the cases to which the instrument has been applied, the process would be quite simple, owing to the magnitude of the quantities involved. The fact that the angle can be obtained is valuable in those cases where curves are taken under fleeting or unknown conditions, in which other methods could not be applied.

[Contribution from the John Harrison Laboratory of Chemistry.]

SOME OBSERVATIONS ON COLUMBIUM.

BY ROY D. HALL AND EDGAR F. SMITH.

(*Read May 19, 1905.*)

The starting-out material in this study was columbite from Lawrence County, South Dakota. Its specific gravity equaled 5.86. It contained 81 per cent. of the mixed oxides of columbium and tantalum. The total quantity of substance decomposed by fusion with acid potassium sulphate (58.5 kilograms) was 21.3 kilograms. Each fusion was made in a platinum dish, using 100 grams of mineral and 275 grams of acid potassium sulphate. While still liquid the mass was poured into a porcelain dish. When cold the fusion separated readily from the dish and was broken into small pieces, which were boiled with water in large No. 11 evaporating dishes until thoroughly disintegrated; when they were transferred to precipitating jars and the hydrates washed by decantation until the wash water gave no precipitate or only a slight precipitate with ammonium hydroxide. The solution and the washings were evaporated to dryness. The residue was designated part I. The moist hydrates of columbium and tantalum were covered with ammonium sulphide and allowed to stand for several days. This ammonium sulphide solution was decanted and designated part II. The remaining oxides were finally treated with very dilute sulphuric acid and then thoroughly washed with water. The washings and the diluted sulphuric acid solution were also evaporated to dryness and marked part III. The residue labeled part I contained potassium and the bases from the mineral in the form of sulphates. It was dissolved in water, poured into five-gallon jars and there precipitated with a slight excess of ammonium hydroxide. Having decanted the supernatant liquid the precipitate was washed once with water, after which the hydrates were covered with a solution of ammonium carbonate and allowed to stand for several days. The ammonium carbonate solution was then siphoned off, acidulated with dilute hydrochloric acid, and any metal present precipitated

with a slight excess of ammonium hydroxide. The hydrate obtained in this way was dissolved in dilute hydrochloric acid, and an excess of ammonium carbonate, together with ammonium sulphide, added to its solution. The iron separated in the form of sulphide and with it there was a small amount of titanium. The filtrate from this precipitate was boiled with hydrochloric acid and ammonium hydroxide added. The hydrate which was precipitated was ignited and tested as to its photographic power. It gave a picture after an exposure of five days. It contained uranium. It showed the greenish color characteristic of U_3O_8. After this it was fused with acid potassium sulphate, taken up in water and the solution boiled. A precipitate formed on cooling but disappeared on warming, thus indicating the presence of members of the cerium group or of zirconium. On the addition of ammonium hydrate there separated a hydrate which, after filtration and washing, dissolved completely in a solution of oxalic acid. This pointed to the presence of zirconium. The hydrates were again precipitated, dissolved in sulphuric acid, and the solution neutralized with potassium carbonate and saturated in the cold with potassium sulphate. By this precipitation the zirconium was obtained in the form of insoluble double sulphate, while the uranium remained in solution. After filtering out the zirconium potassium sulphate it was dissolved in hydrochloric acid and zirconium hydrate precipitated with ammonium hydroxide. It was well washed with water and dissolved in hydrofluoric acid. An equivalent amount of potassium carbonate was added and, on evaporation, potassium zirconium fluoride crystallized out. Three grams of this salt were obtained.

Analysis. — 0.5043 gram of the salt ignited with sulphuric acid gave 0.5272 gram of $K_2SO_4 + ZrO_2$, and contained 0.2212 gram of ZrO_2, leaving 0.3060 gram of K_2SO_4.

	Calculated K_2ZrF_6.	Found.
2KF	41.05	40.47
ZrF_4	58.95	59.52
	100.00	99.99

The uranium in the filtrate from the zirconium was precipitated with ammonium hydroxide, dissolved in hydrochloric acid, and an excess of sodium hydroxide added to this to obtain the glucinum. This was not found. The uranium was changed to nitrate and the

solution allowed to evaporate, when large characteristic crystals of uranium nitrate separated. The solution decanted from the original ammonium hydroxide precipitate, which contained manganese and allied elements, was treated with an excess of sodium carbonate. The precipitate produced was allowed to settle, the supernatant liquid decanted into other jars, and hydrogen sulphide passed through it. A small amount of a black sulphide was obtained. It consisted of zinc, iron, copper and nickel (from the crucible tongs). The precipitate produced by sodium carbonate contained manganese, zinc and iron. Ten grams of it were dissolved in hydrochloric acid and the iron removed by the basic acetate method. The zinc was then precipitated as sulphide. The latter was changed to chloride and tested for gallium. Not a trace of the latter was found. Zinc lines alone were shown in the spectrum.

Tin and tungsten were contained in part II. Part III was not further examined. It may be concluded, therefore, that the columbite from South Dakota contains as acids: tantalum, columbium, titanium, silicon, zirconium, tin and tungsten; as bases: iron, maganese, zinc, uranium, copper (?) and nickel (?).

The moist metallic acids, after having been washed with dilute sulphuric acid, were brought into a large platinum dish and dissolved in fairly concentrated hydrofluoric acid. This solution was then filtered, through a hot water funnel, from undecomposed mineral and from potassium silicofluoride (due to the presence of some potassium sulphate in the moist oxides). The hydrofluoric acid solutions were collected in large rubber dishes and sufficient potassium hydroxide was introduced to convert the tantalum into potassium tantalum fluoride, most of which separated out and was removed by filtration. This precipitate was dried as far as possible by suction. It was washed once and then allowed to dry in the air. It weighed 11 kilograms. The mother-liquor from the potassium tantalum fluoride was evaporated in stages, potassium hydrate being added. The columbium separated usually in hexagonal, hard, short crystals, such as separate from a strongly acid solution containing an insufficient amount of potassium fluoride. The total residue obtained in this way amounted to about 8 to 10 kilograms. These residues were decomposed by treating them with twice their own weight of sulphuric acid, heating gently until the bulk of the hydrofluoric acid was expelled, and then evaporating

until the mass fumed strongly and maintaining the temperature until the excess of sulphuric acid had been almost completely driven out. Several hours were required for this. It is necessary in order to get rid of the hydrofluoric acid. The residual mass was boiled with water to extract the bases which dissolved as sulphates. The insoluble hydroxides were thoroughly washed and dissolved in hydrofluoric acid. The first crop of crystals, obtained by evaporation with potassium hydroxide, was removed and the mother-liquor then evaporated to dryness with sufficient potassium hydroxide to change all of the metallic acids into double fluorides. A portion of these crystals (first crop) was dissolved in water and the tantalum removed by adding dilute potassium hydroxide to the solution, which, after the formation of a permanent precipitate, was boiled for some time. The precipitate consisted mainly of potassium tantalum oxyfluoride. It was filtered out and the filtrate evaporated to dryness. The residue was baked for some time at 200°. By this procedure some hydrofluoric acid was expelled and, on taking up the residue with water and boiling, more potassium tantalum oxyfluoride separated. By repetition of this process all of the tantalum was removed from the solution. The only test relied upon for the detection of tantalum was the solution of this precipitate in a drop of hydrofluoric acid and evaporation to crystallization. If needles separated their solubility in water was used to ascertain whether they were potassium tantalum fluoride or potassium columbium oxyfluoride. It is true that this test consumes considerable time, yet it is the only satisfactory means of determining with which of the metals the chemist is dealing. The formation of a precipitate by protracted boiling of a dilute solution of potassium tantalum fluoride is not conclusive, for Krüss and Nilson (Ber. 1881, 1676) have shown that potassium columbium oxyfluoride deposits under like conditions a small amount of a salt containing less fluorine. Further, the double fluoride must be recrystallized several times, so that it will be sufficiently free from acid that tantalum, if it is present in small amounts, may be precipitated by boiling.

Having freed the double fluoride from tantalum it was dissolved in water and hydrogen sulphide conducted through its solution. A slight precipitate of platinum sulphide was obtained. The filtrate from it was evaporated to dryness and the residue baked.

On dissolving in water more platinum sulphide was found, but when hydrogen sulphide was conducted through the filtrate no further precipitation took place. The first crop of crystals got by the evaporation of this solution showed the usual form of potassium columbium oxyfluoride. They were allowed to dry in the air and labeled crystals No. 1 (A). The filtrate from them was reduced to a small bulk. Strong hydrofluoric acid was added when the needles of potassium columbium fluoride (K_2CbF_7) separated. These were dried between bibulous paper and labeled crystals No. 2 (B). Samples from these two crops of crystals were analyzed.

Analysis of No. 1 (A):

0.53 gram of salt gave 0.2346 gram of oxide and
0.3161 gram of potassium sulphate

$$0.2346 : 0.3161 :: x/2 : 174 \qquad x = R_2O_5 = 258.2.$$

	Calculated. $K_2CbOF_5H_2O$.	Found.
K_2SO_4	57.81	59.64
Oxide	44.52	44.26

The crucible in which the ignition of oxide occurred was stained. This was undoubtedly due to the presence of tin, which had not been removed, although hydrogen sulphide had been conducted through the solution of the double fluoride.

Analysis of No. 2 (B):

0.8428 gram of salt gave 0.3635 gram of oxide and
0.4803 gram of potassium sulphate.

0.4811 gram of salt gave 0.2082 gram of oxide and
0.2775[1] gram of potassium sulphate.

$$0.3635 : 0.4803 :: x/2 : 174 \qquad x = 263.4.$$
$$0.2082 : 0.2775 :: x/2 : 174 \qquad x = 250.1.$$

	Calculated K_2CbF_7.	Found.	Found.
K_2SO_4	57.05	56.99	57.68
Oxide	43.93	43.13	43.28

[1] Probably too high because it was not heated enough to expel all of the sulphuric acid.

Specific gravity of oxide (B):

18.5924 pyknometer + water, $t = 18°$		
.2346 gram of oxide taken		
18.8270		
18.7760 pyknometer + water + oxide	.2346	
.0510 gram water displaced	.0510	4.60 sp. g.

To determine the titanium content of the columbium oxide recourse was had to a comparison of the color tint produced by hydrogen peroxide in an oxalate solution against known amounts of titanium hydrate dissolved in oxalic acid. Thus, 0.2262 gram of columbium oxide was fused with acid potassium sulphate and the fusion dissolved in oxalic acid and diluted to 50 cubic centimeters. It gave a color equivalent to 0.4 cubic centimeter of the standard titanium solution (1 c.c. contained 0.00106 gram of titanium dioxide). In other words, by this test the columbium oxide was thought to contain 0.000424 gram of titanium dioxide, or .18 %.

Solubility of Crystals A.

One part of the salt was found to be soluble in a little over 12 parts of water. This is the solubility of potassium columbium oxyfluoride.

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100 grams of the residues obtained by the evaporation of mother-liquors (page 180) to dryness were dissolved in water and fractionally crystallized. After having removed as much of the tantalum as possible by introducing dilute potassium hydroxide into the boiling solution until a rather considerable and permanent precipitate was obtained, the solution was boiled for some time. The first fraction of crystals (2) and the third fraction of crystals (3) were removed, after which hydrofluoric acid was added to the mother-liquor, from which there separated a crop of needles, which we shall designate crystals 4. These last were recrystallized from hydrofluoric acid. They probably contained silicon and tantalum. The acid mother-liquors from these different crops of crystals were treated as described by Hermann (*J. pr. Chem.*, Series 2, vol. 15, 105, 1877). That is, they were treated with 20 parts or two liters of water and 150 grams of sodium hydroxide. A clear solution resulted, from which a fine crystalline precipitate separated. The filtrate from

this precipitate gave no reduction test when treated with acid and zinc, nor was anything obtained from it after having added dilute sulphuric acid and a slight excess of ammonium hydroxide. It was free from earthy bases and metallic acids.

The crystals of the sodium salt (2.5 grams), obtained as outlined in the last paragraph, dissolved almost completely in 20 parts of boiling water and separated in well-defined forms from the cold solution. A portion of this salt heated in a salt of phosphorus bead imparted a blue color to the latter in the reducing flame.

The next step was to decompose the solution of this crystalline sodium salt with dilute sulphuric acid. The solution was hot. The precipitate which separated was thrown upon a filter and washed, after which it was dissolved in hydrofluoric acid and an equivalent amount of potassium carbonate added in order to form potassium columbium oxyfluoride. The solution was evaporated to dryness upon a water bath, the residue repeatedly moistened, and evaporation to dryness repeated until the odor of hydrofluoric acid could not be detected by the smell; then the salt was baked, taken up in water, and the solution boiled for some time. A trace of tantalum oxyfluoride separated. It was filtered out. On evaporation to crystallization the leafy, characteristic crystals of potassium columbium oxyfluoride appeared. They were dried between bibulous paper and then analyzed.

Analysis:

0.5502 gram of salt gave 0.2452 gram of oxide and
0.3224 gram of potassium sulphate

$0.2452 : 0.3224 :: x/2 : 174 \qquad x = 264.6.$

	Calculated $K_2CbOF_5H_2O$.	Found.
Oxide	44.52	44.56
K_2SO_4	57.81	58.60

A portion of crystals No. 4 (page 182) was recrystallized and analyzed.

0.5588 gram of sample gave 0.2407 gram of oxide and
0.3232 gram of potassium sulphate

$0.2407 : 0.3232 :: x/2 : 174 \qquad x = 259.2.$

	Calculated K_2CbF_7.	Found.
Oxide	43.93	43.08
K_2SO_4	57.05	57.84

Analysis of recrystallized portion of crystals (4), page 182.

.5588 gram of sample gave .2407 gram of oxide.

.3232 gram potassium sulphate.

$.2407 : 3232 :: x/2 : 174 \quad x = 259.2.$

	Calculated. K_2CbF_7.	Found.
Oxide	43.93	43.08
K_2SO_4	57.05	57.84

The results of analysis as well as the behavior points to the fact that the oxide contained in these residues is mainly columbium oxide, Cb_2O_5, with a small portion of another oxide causing the equivalent weights obtained to be too low. These results may in part be due to the presence of some potassium silicofluoride, but more likely to potassium titanium fluoride. Yet these last fractions of double fluoride in which the titanium should be concentrated show only very small amounts. Starting with so much material the last fractions should show more titanium if it is present in the mineral in appreciable amounts.

The only test for small amounts of titanium which we have are the hydrogen peroxide test of Schönn, Jahresberichte, 1893, 901, and the chromotropic acid test used by Geisow (Dissertation, 1902). Of these the former is the only one relied on, and it offers the only direct evidence which we have for the presence of titanium in the potassium columbium oxyfluoride obtained from columbite.

The methods applicable in the preparation of columbium oxide relatively free from titanium are as follows:

1. Crystallization of potassium columbium fluoride (K_2CbF_7) which is not isomorphous with potassium titanium fluoride. The difficulty in this case is that the hydrofluoric acid increases the solubility of the columbium body and decreases that of the titanium double fluoride so that the titanium would have less tendency to concentrate in the mother liquors.

2. Fractional precipitation with dilute ammonium hydroxide. The columbium hydrate is precipitated first and the titanium concentrated in the last fractions. No fraction consists entirely of titanium hydrate; even the last fraction is largely columbium hydrate.

3. The formation of the chloride or oxychloride of columbium and the chloride of titanium and separating these by distillation.

4. Treatment of the hydrates with cold, fairly concentrated sulphuric acid, in which the titanium hydrate should dissolve and leave the columbium.

All of these methods were tried in the endeavor to obtain sufficient titanium from the columbium to identify it and prepare some of its derivatives, *e. g.*, the potassium double fluoride. In order to try out method "1" the remainder of the residues (page 180)—2 to 3 kilos—was crystallized twice from hydrofluoric acid, thus getting potassium columbium fluoride (K_2CbF_7). The mother liquors were united. They equaled 600 c.c. They were neutralized with dilute ammonium hydroxide; the precipitated hydrate filtered out and the filtrate made alkaline with a large excess of ammonium hydroxide, which gave a further precipitate. This last hydrate was filtered out and dissolved in hydrofluoric acid. Potassium carbonate was added and the solution evaporated to dryness on a water bath, the residue taken up in water and crystallized. The crystals obtained were short stubby needles. They were evidently not potassium columbium oxyfluoride (K_2CbOF_5). Their quantity was too small to recrystallize, but they were analyzed:

0.4672 gram of sample gave 0.1740 gram of oxide = 37.6 per cent.
" " " " " 0.3050 gram of K_2SO_4 = 65.3 per cent.

The sp. gr. of the oxide was found to be 5.2, although too little of it was at hand for accurate work. The determination of the titanium in the oxide colorimetrically gave 0.0106 gram of TiO_2 = 6.1 per cent.

The salt originally taken showed 0.62 per cent. of its oxide to be TiO_2 by the colorimetric determination, while the double fluoride of potassium and columbium obtained showed a TiO_2 content equal to .25 per cent. of its oxide. Hence it would seem that by method "1" the titanium or oxide with lower sp. gr. and molecular weight did concentrate in the mother liquors.

Crystals 2 and 3 (page 182) were combined. Their total weight was about one kilo. This, in portions of 100 grams at a time, was dissolved in about 2 liters of water and fractionally precipitated with ammonium hydroxide, using dilute alkali and working in the cold with constant stirring. The alkali was added until the solution was barely acid to litmus, the precipitate formed was filtered off and the filtrate made alkaline with an excess of the precipitant. This

second fraction contained about 3–4 grams of oxide from each 100 grams of double fluoride taken. These ten last fractions were combined and dissolved in hydrofluoric acid, 15 grams of potassium hydroxide added, then dilute ammonium hydroxide until slightly acid, and the precipitate filtered out. It was marked "A." Ammonium hydroxide was then added to the filtrate until litmus showed the reaction to be just neutral. The precipitate was designated "B." "C" was obtained in the filtrate from "B" by adding a large excess of ammonium hydroxide. It (C) presumably should contain most of the titanium from the 1,000 grams of double fluoride taken. The oxide actually present in it was changed to double fluoride by dissolving in hydrofluoric acid and adding potassium carbonate. The first crop of crystals was obtained from strong hydrofluoric acid. It recrystallized from the same in needles. These were analyzed :

0.6954 gram of sample gave 0.3018 gram oxide and
0.3900 gram potassium sulphate,

$$.3018 : .3900 :: x/2 : 174, \qquad x = 269.3.$$

	Calculated K_2CbF_7.	Found.
Oxide	57.05	56.09
K_2SO_4	43.93	43.40

The sp. gr. of the oxide equaled 4.45. 0.3 gram of it showed the presence of the equivalent of .0025 gram of TiO_2, or 0.83 per cent.

The needles from "C," not taken for analysis, and the mother liquor were combined and evaporated to dryness on a water bath to expel the excess of hydrofluoric acid. This was repeated once. The solution of the salt was then fractionally precipitated with amonium hydroxide, the fractions up to the point where litmus showed a slightly alkaline reaction being discarded, when the filtrate from them was made strongly alkaline with ammonium hydroxide. The precipitate obtained was changed to its potassium, double fluoride. About 2.5 grams of the double salt were got.

Analysis :

0.7248 gram of sample gave 0.3014 gram of oxide and
0.4205 gram of K_2SO_4

$$0.3014 : 0.4205 :: x/2 : 174 \qquad x = 249.4.$$

	Calculated $K_2CbOF_5H_2O$.	Found.
Oxide	57.81	58.02
K_2SO_4	44.52	41.58

The sp. gr. of the oxide was found to be 4.667. 0.2930 gram of oxide gave a color with hydrogen peroxide equivalent to .0322 gram of $TiO_2 = 11$ per cent.

The crucible in which the oxide was ignited was deeply stained. The analysis and the color test showed the presence of titanium, while the stain on the crucible and the high sp. gr. of the oxide could be due to tin in considerable amount, which is precipitated in the last fractions on fractional precipitation with ammonium hydroxide.

The crystals and the mother liquor remaining from this salt were dissolved in boiling water and an excess of sodium hydrate added, when a heavy flocculent precipitate separated. This was filtered, boiled with water and the insoluble portion changed to double fluoride. It was again taken up in boiling water and an excess of sodium hydroxide added. The precipitation was not complete. The portion precipitated was treated with boiling water, filtered, and the filtrate found to contain a large amount of titanium. That portion of the precipitate insoluble in water was changed to double fluoride.

Analysis:

0.5570 gram of sample gave 0.2248 gram of oxide and 0.3468 gram of K_2SO_4

$0.2248 : 0.3468 :: x/2 : 174 \qquad x = 225.6.$

The sp. gr. of the oxide was found to be 4.2. The oxide gave a color with hydrogen peroxide showing the presence of about 21 per cent. TiO_2.

Crystals "A" (page 181) were changed to double fluoride and recrystallized.

Analysis:

0.7184 gram of sample gave 0.3188 gram of oxide and 0.4176 gram of potassium sulphate.

$0.3188 : 0.4176 :: x/2 : 174 \qquad x = 265.7.$

	Calculated $K_2CbOF_5H_2O$.	Found.
Oxide	44.52	44.38
K_2SO_4	57.81	58.13

The sp. gr. of the oxide was found to be 4.481. 0.3160 gram of oxide gave a color with hydrogen peroxide equivalent to .0022 gram TiO_2 = .7 per cent.

Crystals "B" (page 181) analyzed as follows:

0.8098 gram of sample gave 0.3614 gram of oxide and
0.4708 gram of K_2SO_4

$$0.3614 : 0.4708 :: x/2 : 174 \qquad x = 267.0.$$

	Calculated $K_2CbOF_5H_2O$.	Found.
Oxide	44.52	44.63
K_2SO_4	57.81	58.14

The sp. gr. of the oxide was found to be 4.864. 0.3600 gram of oxide gave with hydrogen peroxide a color equivalent to .0013 gram of TiO_2 = .36 per cent.

Having failed to get any evidence of the existence of neptunium in the last fractions of the double fluoride from the South Dakota mineral, it was decided to test some of the mineral from Haddam, Conn., the source of the material used by Hermann in his investigation. The last fractions of the potassium double fluoride from 5.87 kilos of columbite from Haddam, Conn., amounting to 100 grams, were dissolved in boiling water and an excess of sodium hydroxide added. The precipitate obtained was partly crystalline and partly flocculent, as described by Hermann. It was filtered out, dried on a porous plate, and boiled with 25 parts of water. The crystals dissolved leaving a yellowish residue evidently containing much iron. This residue gave a yellow colored bead in the reducing flame containing so much iron that it was impossible with a small blowpipe to keep it all reduced. Is it not probable that this is what Hermann supposed was neptunium?

This salt was fused with acid potassium sulphate to remove the iron, the oxide remaining after extracting the fusion with boiling water was changed to double fluoride, dissolved in boiling water, and an excess of sodium hydroxide added. The precipitate obtained was crystalline and perfectly soluble in water, leaving an inappreciable residue. From all of which it may be inferred that

the material from the Haddam locality showed no more evidence of neptunium than did that from South Dakota.

Ten kilograms of the main bulk of the potassium columbium oxyfluoride were crystallized from strong hydrofluoric acid. Five hundred grams were taken at one time and the mother liquors from the two fractions combined, evaporated one half, and another crop of crystals removed. The mother liquors from these were united and evaporated, the crystals obtained were recrystallized, the mother liquors from the recrystallization combined and evaporated to dryness with sulphuric acid. The oxide obtained from that portion evaporated to dryness was 5 grams. The fraction of crystals immediately preceding, 60 grams in weight, was decomposed with sulphuric acid and the oxide obtained from it. The 5 grams of oxide and about one-half of the oxide from the 60 grams of double fluoride were heated in carbon tetrachloride vapors, taking about 2 grams of oxide at a time. The more volatile portion, which should contain the most of the $TiCl_4$, was distilled away from the $CbOCl_3$. The portions of this liquid were combined, the oxides — 3 grams — obtained from it, and these oxides again heated in CCl_4. Again only the liquid portion and that of the solid which was carried over mechanically was taken. The oxide from this portion was changed to double fluoride.

Analysis:

0.5678 gram of sample contained 0.2196 gram of oxide and 0.3390 gram of K_2SO_4.

$$0.2196 : 0.3390 :: x/2 : 174 \qquad x = 225.4.$$

	Calculated $K_2CbOF_5H_2O$.	Found.
Oxide	44.52	38.6
K_2SO_4	57.81	59.7

Amount of TiO_2 in the oxide .0594 gram = 29.7 per cent.

The oxide from the salt taken for analysis was combined with the oxide from the double fluoride not taken for analysis and this with the remaining half of the oxide from the 60 grams of double fluoride mentioned above was mixed with the oxide from all the previous double fluorides which had been tested for titanium and shown its presence in a fair degree. This mixture of oxides was heated in a current of sulphur monochloride, the chloride formed collected

in a receiver, and this was then heated until all of the sulphur monochloride was distilled out. This sulphur monochloride and any other chlorides which it might contain was again distilled to remove the last of the columbium chloride which might have been carried over mechanically. It was then treated with water and oxalic acid, the sulphur filtered off, and any oxide dissolved in the oxalic acid precipitated with ammonium hydroxide. This hydrate was changed to potassium double fluoride.

Analysis :

0.5444 gram of sample gave 0.1952 gram of oxide and
0.3850 gram of potassium sulphate

$0.1952 : 0.3850 :: x/2 : 174 \qquad x = 175.9.$

	Calculated. $K_2CbOF_5H_2O$.	Calculated.	Found.
Oxide	44.52	33.33	35.85
K_2SO_4	57.81	72.50	70.72

0.0310 gram of the oxide was found to contain 0.244 gram TiO_2, or 78.7 per cent.

A solution of the oxide in hydrochloric acid reduced with zinc to an amethyst or violet color ; the oxide also gave a violet titanium bead in the reducing flame with salt of phosphorus.

It would seem that about 80 per cent. of the oxide from this double fluoride was TiO_2.

The remainder of the double fluoride, about .5 gram, was dissolved in the mother liquor from which it came by heating, and an excess of sodium hydrate added. A flocculent precipitate formed. After cooling, this was filtered off and the filtrate acidified with hydrochloric acid and tested for metallic acids with ammonium hydroxide. A precipitate was obtained, which was filtered out and, after washing thoroughly, dissolved in hydrochloric acid.

Upon passing hydrogen sulphide through this solution a heavy precipitate of yellow stannic sulphide was obtained, showing that tin had been carried over with the titanium by the sulphur monochloride.

The precipitate formed by the excess of sodium hydroxide was drained thoroughly and boiled up with water. Nothing went into solution, as would have happened had there been any sodium columbate in the precipitate. This well washed precipitate was

dissolved in hydrofluoric acid and potassium carbonate added to change it to the potassium double fluoride.

Analysis of the crystals obtained:

0.1893 gram of sample gave 0.0642 gram of TiO_2 and
0.1366 gram of K_2SO_4

	Calculated.	Found.
Oxide	33.33	33.91
K_2SO_4	72.50	72.16

The determination of the TiO_2 colorimetrically gave .0636 gram. The salt was undoubtedly potassium titanium fluoride, proving conclusively the presence of titanium in columbite.

Behavior of Solutions of the Double Fluorides of Columbium and of Titanium with a Variety of Bases.

Excess of sodium hydroxide was found to precipitate titanium completely from a solution of potassium titanium fluoride, while with potassium columbium oxyfluoride it gave a precipitate soluble in slight excess but again insoluble and separating in a crystalline form from a large excess of the sodium hydroxide. The precipitate formed in the case of the titanium was insoluble in water, while in the case of columbium the crystalline deposit was completely soluble in hot water. It was hoped that this difference of behavior might afford a means of separating these two elements. To test this experiments were tried as follows:

1. 0.9600 gram of $K_2CbOF_5 + H_2O$, containing 0.4272 gram of Cb_2O_5, and 1.1600 gram K_2TiF_6, containing 0.3753 gram of TiO_2, were dissolved in 200 c.c. water, brought to boiling and an excess of sodium hydroxide added. The precipitate which formed was partly crystalline and partly flocculent. The solution was allowed to stand over night. The precipitate was filtered out, drained, and washed back into a platinum dish. It was covered with 200 c.c. of water, brought to boiling, filtered hot, and washed with hot water. The filtrate which should contain most of the columbium and none of the titanium was brought to boiling and sulphuric acid and ammonium hydroxide added. The hydrate obtained was ignited to oxide and weighed 0.1640 gram. It was found to contain .0117 gram of TiO_2. The titanium content was determined colorimetrically by fusing with potassium acid sulphate, dissolving

the fusion in oxalic acid and comparing the color developed with hydrogen peroxide with that of a titanium solution, of known strength, in oxalic acid.

Part insoluble — 0.2749 Cb_2O_5, 0.3636 TiO_2

$TiO_24Cb_2O_5$ soluble portion; $Cb_2O_54TiO_2$ insoluble portion.

2. A mixture containing 0.1270 gram K_2TiF_6, or .0423 gram TiO_2 and 2.5280 grams $K_2CbOF_5.H_2O$, or 1.1376 gram Cb_2O_5, was treated as above. The precipitate was nearly all crystalline. That part of it insoluble in water weighed .0470 gram and contained .0074 gram of TiO_2 leaving .0349 gram of TiO_2 in solution (by far the greater quantity).

3. 0.2830 gram K_2TiF_6, containing .0943 gram TiO_2, and 2.7040 grams $K_2CbOF_5H_2O$, containing 1.2168 grams Cb_2O_5, were treated as before. The precipitate was chiefly crystalline. A small part of it was flocculent. The part insoluble in water weighed .0740 gram and contained .0148 gram TiO_2, showing that .0795 gram TiO_2 went into solution and would be found with the bulk of the columbium.

4. 0.6790 gram K_2TiF_6, containing .2263 gram TiO_2, and 2.2530 grams $K_2CbOF_5H_2O$, containing 1.0139 grams Cb_2O_5, were treated as before. The precipitate contained a considerable amount of flocculent material. The part insoluble in water weighed 0.1720 gram and contained 0.0710 gram TiO_2, leaving 0.1553 gram of TiO_2 in solution.

The action of potassium hydroxide was also tried. It gave a precipitate with columbium, soluble in an excess, and reprecipitated by greater excess. When the solution was evaporated pearly plates of potassium columbate separated out. With a solution of K_2TiF_6 a heavy precipitate was obtained, but the filtrate gave a slight test for titanium.

1.3130 gram K_2TiF_6, containing .4377 gram of TiO_2, and 1.0060 gram $K_2CbOF_5H_2O$, containing .4467 gram Cb_2O_5, were dissolved in 200 c.c. of water and the solution brought to boiling, when an excess of potassium hydroxide was added. The precipitate obtained weighed 0.5900 gram after ignition. The filtrate gave a very pronounced test for titanium.

Solutions of K_2TiF_6 and K_2CbOF_5 were studied with various organic bases in the hope that differences of behavior might pre-

sent themselves which would lead to a quantitative separation of these two elements.

Reagent.	Solution of K_2TiF_6.	Solution of K_2CbOF_5.
1. Mono-methylamine,	Precipit. complete,	Precipit. soluble excess.
2. Di-methylamine,	“ “	“ “ “
3. Tri-methylamine,	“ “	“ “ “
4. Tetra-methylamine,	“ “	“ “ “
5. Mono-ethylamine,	“ “	“ “ “
6. Di-ethylamine,	“ “	“ “ “
7. Tri-ethylamine,	“ “	“ by large excess. insoluble excess. dif. soluble in water.
8. Di-propylamine,	“ “	“ soluble excess.
9. Amylamine,	“ “	“ “ “
10. Iso-butylamine,	“ “	“ “ “
11. Allylamine,	“ “	“ “ “
12. Ethylenediamine,	“ “	“ “ “
13. Propylenediamine,	“ “	“ “ “
14. Butylenediamine (secondary),	“ “	“ “ “
15. Butylenediamine (normal)	“ “	“ “ “
16. Hexylamine,	“ “	“ “ “
17. Benzylamine,	“ “	“ “ “
18. Benzylmethylamine,	“ “	“ “ “
19. Piperidine,	“ “	“ “ “
20. Camphylamine,	“ “	slightly soluble excess.
21. Di-benzylamine,	“ “	Precipit. complete.
22. Pyridine,	“ “	“ “
23. Di-isobutylamine,	“ “	“ “
24. Tri-propylamine,	“ “	“ “
25. Di-amylamine,	“ “	“ “
26. Heptylamine,	“ “	“ “
27. Toluylenediamine (meta),	Partial precipitation,	“ “
28. Picoline,	“ “	“ “
29. Tri-isobutylamine,	Slight precipitation,	“ nearly but not quite complete.
30. Bornylamine,	“ “	“ not complete.
31. Aniline,	Precipit. not complete,	“ heavy but not complete.
32. Toluidine (m),	Slight precipitation,	“ “ “
33. Mono-methylaniline,	“ “ after 24 hours,	“ “ “
34. Mono-ethylaniline,	Slight prec. on standing,	“ slow—incomplete.
35. Isoquinoline,	“ “ “	“ heavy—incomplete.
36. Quinoline,	“ “ “	“ nearly complete,

Reagent.	Solution of K_2TiF_6.	Solution of K_2CbOF_5.
37. Hexylmethylenetetramine,	Slight prec. on standing,	Prec. heavy—incomplete.
38. Bromaniline (m),	No precipitation,	Slight prec. on standing.
39. Chloraniline (o),	" "	" " "
40. Di-chloraniline,	" "	" " "
41. Di-ethylaniline,	" "	" " "
42. Chloraniline (p),	" "	" " "
43. Di-methylaniline,	" "	" " "
44. Xylidine (p),	" "	Precipit. slow—incomplete.
45. Xylidine (o),	" "	" " "
46. Xylidine (m),	" "	" " "
47. Tetra-hydroquinoline,	" "	Slight prec. on standing.
48. Benzylaniline,	" "	No precipitation.
49. Di-phenylamine,	" "	" "
50. Tri-benzylamine,	" "	" "
51. Naphthylamine (β),	" "	" "
52. Naphthylamine (a),	" "	" "
53. Nitronaphthalene,	" "	" "
54. Bromphenylhydrazine,	" "	" "
55. Nitrophenylhydrazine,	" "	" "
56. Benzidine,	" "	" "
57. Nitraniline (o),	" "	" "
58. Nitraniline (p),	" "	" "
59. Nitraniline (m),	" "	" "
60. Diphenyl,	" "	" "
61. Diphenyl carbonate,	" "	" "
62. Methyl carbonate,	" "	" "
63. Ethyl carbonate,	" "	" "
64. Piperine,	" "	" "
65. Mono-chlorhydrin,	" "	" "
66 Tri-chlorhydrin,	" "	" "
67. Di-bromhydrin (β),	" "	" "
68. Nitroso-dipropylin,	" "	" "
69. Nitroso-diethylene,	" "	" "
70. Nitroso-dimethylene,	" "	" "
71. Succinimide,	" "	" "
72. Methyl-diphenylamine,	" "	" "
73. Tetra-nitromethylaniline,	" "	" "
74. Bromamiline,	" "	" "

The behavior of the bases which react with the above solutions of titanium and columbium may be divided into the following classes:

1. Those which precipitate the titanium completely, and while they precipitate the columbium dissolve it upon the addition of an

excess of the reagent to form columbates. This class while showing pronounced difference of behavior is useless as a means of separation, for upon treating a solution containing both titanium and columbium with one of these reagents the titanium was found both in the soluble and in the insoluble portion. Columbium was also found in the titanium precipitate. The probable explanation for this is that a columbate was formed which dissolved the freshly precipitated titanium hydrate to a salt of a complex titanoso-columbic acid, which was soluble, and also a small amount of an acid salt or a free acid containing an excess of titanium, which was insoluble.

2. To the second class of reagents belong those which precipitate the hydrates of the two elements and are not sufficiently basic to dissolve the columbium hydrate and form columbates. Those reagents which are sufficiently basic to completely precipitate the columbium are strong enough to partially precipitate the titanium. Quinoline seemed the most promising of all the reagents which were tried.

3. Those reagents which gave only a partial precipitation with columbium and no precipitation with titanium solutions did not precipitate columbium hydrate free from titanium, from a solution containing both titanium and columbium. The hydrate precipitated always gave a strong test for titanium after dissolving it in oxalic acid. This may have been due in part to the extreme difficulty encountered in washing the precipitate free from mother liquor.

4. The remaining reagents precipitated neither titanium nor columbium.

REACTIONS OF THE DOUBLE FLUORIDES OF COLUMBIUM, TITANIUM, TANTALUM, TIN AND TUNGSTEN WITH VARIOUS REAGENTS IN CONCENTRATED SULPHURIC ACID.

A small amount of the reagent was dissolved in eight to ten drops of concentrated sulphuric acid on a glazed porcelain surface and the crystalline double fluoride introduced into this acid solution. In most cases the color was destroyed upon diluting with water. No color was imparted to tin solutions by any of the reagents which appear below.

Reagent.	Ta.	Cb.	Ti.	W.
Codeine,	No color,	No color,	Faint pink; may be due to morphine,	Light brown; on standing trace purple.
Morphine,	Faint yellow,		Red to brown; very delicate,	Gray brown, becoming purple, H_2O ppt.
Resorcinol	No color,	No color,	Red brown; fairly delicate,	No color.
Naphthol (β)	"	Faint yellow brown	Coffee brown; very delicate,	Brown, becoming dark blue.
Naphthol (α)	"	Faint brown,	Green to dark greenish brown,	Deep blue; very delicate.
Pyrogallol,	"	Yellow to light brown,	Dull dark red,	Deep red to brown to dirty blue.
Salicylic acid,	"	Very faint yellow,	Deep red,	Reddish yellow.
Cinchonidine,	"	No color,	No color,	On standing a slight purple.
Apomorphia,	"	Yellow brown,	Light red brown,	Purple to brown to green and blue.
Narceine,	"	Brownish yellow,	Brown,	Dirty dark green.
Bebeerina,	"	No color,	Clear brown,	Dark brown to green.
Narcotina,	"	Yellow,	Brown,	Light brown to green.

Strychnia, quinidia, cinchonidine and atropia gave no color with any of the elements tested. Narceine and bebeerina alone in sulphuric acid gave a considerable color, and with them the amount of reagent used must be very small or it will obscure any change produced by the addition of the double fluoride. In this connection it is of interest to note that Levy (*C. R.*, **103**, 1074 and 1195) studied the colors produced by the phenol-like bodies, dissolved in concentrated sulphuric acid, when brought in contact with the oxides of titanium, tin, tantalum, columbium and other elements, with the following results. Columbium could be tested for in the presence of all the others by using codeine, as it gave a pink color, while titanium yielded no color and tantalum but a faint green. Titanium could be tested for by using morphine, with which it gave a carmine color, columbium no color and tantalum a yellow color passing into brown. Tantalum with resorcinol gave a dirty green color, changing to amethyst and rose, while titanium yielded a flesh red color going to chocolate brown, and columbium a yellowish tint. None of the results were dupli-

cated save the morphine test for titanium, which proved exceedingly delicate, yet to have the color show definitely in columbium the latter must contain .5 per cent. of TiO_2. Codeine gave no color with columbium, nor did resorcinol with tantalum, therefore Levy could not have had pure material for his tests.

In our use of these reagents we failed to find satisfactory tests except in the case of morphine for titanium. None answered for columbium in the presence of titanium or for tantalum in the presence of columbium. Resorcinol proved to be a fairly delicate test for titanium. It gave no color with columbium, tantalum or tungsten.

ACTION OF HYDROCHLORIC ACID GAS ON IGNITED COLUMBIC OXIDE.

0.25 gram of ignited columbic oxide was completely volatilized in three hours in a current of dry hydrochloric acid gas. It volatilized as a white powder with no indication of reduction by change of color. The compound formed adhered to the walls of the glass tube, was insoluble in oxalic acid, and only very slowly soluble in concentrated sulphuric acid, requiring long boiling to dissolve a thin layer. It contained hydrochloric acid, as was shown by washing with ammonium hydroxide and testing the washings with silver nitrate and nitric acid. It would be very difficult to collect in a form convenient for analysis, yet this should be done, as the body evidently contains no water, as is given in the formula of a similar body obtained by Smith and Maas (*Zeit. anorg. Chem.*, 7, 96) by passing moist hydrochloric acid gas over the hydrated oxide. It is undoubtedly analogous to the body obtained on heating molybdic acid in hydrochloric acid gas, namely, $MoO_3 2HCl$. It is likely $Cb_2O_5.xHCl$.

ACTION OF SULPHURIC ACID ON THE HYDRATES OF COLUMBIUM AND TITANIUM AFTER RECIPITATION BY AMMONIUM HYDROXIDE FROM SOLUTIONS OF THEIR DOUBLE FLUORIDES.

The method used was to precipitate the hydrates from a weighed amount of the double fluorides, filter and wash as thoroughly as possible, then transfer to a weighed platinum dish, reweigh, the difference being water, after which a weighed amount of sulphuric

acid of definite specific gravity was added and allowed to stand in contact with the hydrates for a definite time. The portion insoluble was filtered off, and the amount of oxide going into solution determined by precipitation with ammonium hydroxide, igniting and weighing. The amount of titanium in the oxide which went into solution was determined colorimetrically.

In making these trials columbium oxyfluoride was used in which the titanium oxide as compared with the columbium oxide was .00095 gram TiO_2, or 0.41 per cent. The specific gravity of the sulphuric acid used was 1.145.

EXPERIMENTS.

1. 1 gram of K_2TiF_6, containing 0.3330 gram of TiO_2, was used to obtain the hydrate. The latter was treated with 40 c.c. of water and 70 grams of sulphuric acid. It dissolved completely in fifteen minutes.

2. 0.4450 gram of columbic oxide, in the form of hydrate, was treated with 40 grams of water and 108 grams of sulphuric acid for one hour. Only a slight precipitate was obtained with ammonium hydroxide in the filtrate. It was not weighed but contained .00032 gram of TiO_2, or .07 per cent. of the total oxide taken, or one-sixth of the total TiO_2 present.

3. Columbic hydrate, containing 0.4450 gram of oxide, was treated with 60 grams of water and 123 grams of sulphuric acid for four hours. The portion which dissolved equaled 0.0060 gram = 1.33 per cent., and contained .000424 gram of TiO_2, or 7 per cent. of the oxide dissolved and about one-fourth of the total titanium present.

4. The hydrate from three grams of columbium oxyfluoride, equivalent to 1.35 grams of oxide, was allowed to stand in contact with 50 grams of water and 100 grams of sulphuric acid for seventeen hours. The acid solution showed 0.0236 gram of oxide = 1.75 per cent., containing .000954 gram TiO_2 = 4 per cent. of oxide dissolved or 17 per cent. of the total TiO_2 present.

5. Hydrate containing 0.445 gram of oxide when treated with 57 grams of water and 85 grams of H_2SO_4 (sp. gr. = 1.435) for 45 hours showed in solution 0.0500 gram = 11.1 per cent., containing 0.0008 gram TiO_2 = 1.6 per cent. of the oxide dissolved or 43 per cent. of the total TiO_2 present.

Known amounts of the two hydrates were next treated together as in the following experiments.

6. 0.2816 gram of K_2TiF_6, containing .0939 gram of TiO_2, and 0.5078 gram of $K_2CbOF_5H_2O$, containing 0.2255 gram Cb_2O_5, were treated with 50 grams of water and 15 grams of sulphuric acid (sp. gr. = 1.435) for four hours. The amount of oxide remaining insoluble was only .07 gram. It was not examined as to its titanium content.

7. The hydrate from 0.2420 gram K_2TiF_6, containing .0807 gram TiO_2, and that from 0.3454 gram of $K_2CbOF_5H_2O$, containing 0.1537 gram of Cb_2O_5, were covered with 70 grams of water and 5 grams of sulphuric acid of sp. gr. 1.435. The amount of oxide in solution after four hours was 0.0800 gram, corresponding well with the weight of the oxide of titanium present, but the insoluble portion was found to contain 0.0350 gram of TiO_2, determined colorimetrically; so that only about one-half of the titanium hydrate had been dissolved out while nearly as much columbium hydrate had gone into solution. The acid used would not have dissolved any columbium hydrate had it been free from titanium hydrate; further it would have dissolved out all of the titanium hydrate had it not been mixed with the columbium hydrate. It may, therefore, be concluded that this method of separation is worthless. It remains to be seen how haloid acids would act.

THE CHROMOTROPIC ACID TEST FOR TITANIUM.

Geisow (Dissertation, 1902) observed that the color developed by chromotropic acid with titanium solutions offered a very delicate test for that element. In concentrated solution it gives a deep red, in dilute solutions, a pink color. The color-giving compound was isolated by Geisow and found to have the following composition: one molecule of chromotropic acid to four of TiO_2 and nine of H_2O.

As it was most important to find some means of estimating the amount of titanium in columbium we were induced to study this reaction of Geisow, using solutions of titanic hydrate in oxalic, sulphuric and hydrochloric acids.

Solutions used:

(*A*) 0.53 gram of TiO_2 dissolved in 3.42 grams of oxalic acid and diluted to 500 c.c. 1 c.c. = .00106 gram of TiO_2 and contained .00684 gram of oxalic acid.

(B) 10 c.c. of (A) diluted to 100 c.c. 1 c.c. = .000106 TiO_2.

(C) 10 c.c. of (B) diluted to 100 c.c. 1 c.c. = .0000106 TiO_2.

(D) 10 grams of oxalic acid in 100 c.c. 1 c.c. = 0.1 gram of oxalic acid.

(E) 1 gram chromotropic acid in 100 c.c.

50 c.c. Nessler tubes, one inch in diameter, were used for all of the tests.

.5 c.c. of (E) in 50 c.c. of water gave a mere trace of color, for which reason the solution to be tested was always compared with another tube containing the same amount of chromotropic acid, thus making allowance for the slight color given by the solution of that reagent.

.15 c.c. of (C) gave a faint pink color when added to 50 c.c. of water containing .5 c.c. of (E); .00000159 gram of TiO_2 in 50 c.c. of water gave a change of color; .3 c.c. of the same solution gave a very distinct coloration, or .00000318 gram of TiO_2 in 50 c.c. More than 1 c.c. of the chromotropic acid gave so much color as to interfere with the delicacy of the test.

EFFECT OF OXALIC ACID.

1 c.c. of (E).

1 c.c. of (D), or 1 gram of oxalic acid in 50 c.c., required 2.6 c.c. of titanium solution (C) to show the characteristic pink color, or .0000275 gram of TiO_2.

1 c.c. of reagent was adopted as the amount best suited to use and was the amount taken in all of the following cases unless otherwise stated.

With 0.2 gram of oxalic acid, .0000339 gram of TiO_2, in 50 c.c. gave a pink color.

With 0.5 gram of oxalic acid, .0000275 gram of TiO_2 was required to give the test for titanium.

1.0 gram of oxalic acid required .0000244 gram of TiO_2 to give the test.

In the presence of 2.0 grams of oxalic acid, .0000244 gram of TiO_2 gave a distinct pink color in 50 c.c., while with 5.0 grams of oxalic acid, .0000265 gram of TiO_2 gave a color.

The amount of oxalic acid seems to have little effect although the presence of the acid diminishes the delicacy of the test, but this is independent of the amount of the acid present when more than 0.1 gram is used.

EFFECT OF THE PRESENCE OF HYDROCHLORIC ACID.

The solution of hydrochloric acid used was one part of concentrated acid to five parts of water.

With 1 c.c. of hydrochloric acid (1:5) and 1 c.c. of chromotropic acid in 50 c.c., .0000795 gram of TiO_2 gave a distinct pink color.

With 2 c.c. of hydrochloric acid (1:5) .00017 gram of TiO_2 was required to give the color.

When 5 c.c. of hydrochloric acid (1:5) was used .000424 gram of TiO_2 gave a pink color to 50 c.c.

10 c.c. of hydrochloric acid (1:5) required .000848 gram of TiO_2 for the color.

20 c.c. of hydrochloric acid (1:5) required .00169 gram of TiO_2 in 50 c.c. to give a definite test for titanium.

It may, therefore, be concluded that the destruction of the color given by chromotropic acid is in proportion to the amount of acid present, so if this test is used hydrochloric acid should be absent.

EFFECT OF SULPHURIC ACID.

With 1 c.c. of sulphuric acid, specific gravity, 1.435, 0.000318 gram of TiO_2 was required to give a pink color in 50 c.c. of solution.

With 2 c.c. of sulphuric acid 0.000742 gram of TiO_2 was required to give the titanium test.

While more dilute solutions of sulphuric acid were not tried it is evident that the effect of the sulpuric acid is roughly proportional to the amount of acid present, and that any appreciable amount of this acid seriously interferes with the delicacy of the test. The same is true of hydrofluoric acid.

In the presence of oxalic acid in any appreciable amount chromotropic acid will show .000025 gram of TiO_2 in 50 c.c. very distinctly. Half that amount could be detected but the color is very faint and its similarity to the color possessed by the solution of chromotropic acid itself renders the detection of this amount uncertain. In making the test it is best to avoid the presence of free mineral acids, as they interfere and generally in direct proportion to the amount of acid present. The neutral chlorides and sulphates are without effect, as Geisow has stated. It is probable that the color developed in oxalate solution could be used to determine the

amount of titanium present by comparison with the color developed by known amounts of titanic acid, but this method would offer no especial advantage over the hydrogen peroxide method.

THE ACTION OF CARBON TETRACHLORIDE ON THE OXIDES OF TITANIUM, COLUMBIUM AND TANTALUM.

According to Demarcay (*C. R.*, **104**, 111) carbon tetrachloride vapor passed over the ignited oxides of columbium, titanium and tantalum changes them to chlorides — in the case of titanium with the formation of an intermediate oxychloride.

Lothar Meyer (*Ber.*, **20**, 681) found no action on oxide of titanium. He did not try the other two.

Delafontaine and Linebarger (*Jr. Am. Ch. S.*, **18**, 532) found that oxide of columbium was changed to oxychloride, $CbOCl_3$, with the formation of a small amount of the chloride. In the case of tantalum the oxide was not driven from the boat but remained behind as a pasty mass, suffering no change to chloride. They suggest this as a possible separation of the two elements columbium and tantalum.

The vapor of carbon tetrachloride was found to act slowly on ignited titanic oxide at a low red heat, some chloride of titaninm being continuously formed. In time all of the oxide was converted into chloride.

The oxide of columbium is readily acted upon by carbon tetrachloride even at a low red heat. The principal product is the white oxychloride. Some of the yellow chloride is simultaneously produced. It continues to be formed in small amounts as the oxychloride is sublimed in the vapors of carbon tetrachloride. Columbium oxide heated in a sealed tube with carbon tetrachloride, is completely changed to chloride after several hours at 200°–225°. The chloride dissolves in carbon tetrachloride and separates from it in large, well-formed, needle-like crystals.

The action of the vapors of carbon tetrachloride on ignited oxide of tantalum is rapid, contrary to Delafontaine and Linebarger, converting it into chloride, which can be readily freed from the carbon tetrachloride and thus obtained pure. If the carbon tetrachloride used contains traces of moisture oxide will be produced by the decomposition of the chloride. This oxide dissolves in the fused chloride and remains as a glassy mass upon sublimation of the

chloride. Therefore, care should be taken in the dehydration of the tetrachloride used; otherwise the product will be contaminated with oxide. This seems to be the best method for the preparation of tantalum chloride in large quantities and in a high state of purity. The chloride is an excellent starting-out material for a redetermination of the atomic weight of tantalum, a number none too definite, as a study of the series of results obtained by Marignac (*Zeit. anal. Chem.*, 5, 478) by the analysis of potassium tantalum fluoride and ammonium tantalum fluoride will show.

The action of carbon tetrachoride on the oxide of columbium also affords an excellent method for the preparation of the oxychloride of that element. It is produced, however, in a very voluminous state, and mats together to a tough felt, completely stopping up any tube used in its preparation. When heated in a sealed tube it condenses on a warm surface to very compact lustrous silky needles. It is very difficult to remove the last traces of columbium pentachloride from this body. This may be done, however, by subliming it in a current of chlorine over ignited oxide, but as long as any carbon tetrachloride is present the columbium chloride will continue to be formed. To make the chloride of columbium it is necessary to have recourse to the action of sulphur monochloride on the oxide or to act on the oxide with carbon tetrachloride in a sealed tube.

PROPERTIES OF COLUMBIUM CHLORIDE.

As already mentioned, columbium chloride is soluble in carbon tetrachloride, forming a yellow colored solution. It is much more soluble when hot than when cold and crystallizes out on cooling in well defined crystals. It is also soluble in sulphur monochloride, the solution saturated in the hot being red in color and depositing yellow crystals of the chloride on cooling. It dissolves in ether with a yellow color. On evaporating this solution on a water bath a thick liquid remains, and an acid vapor is given off, but no crystals separate. Upon ignition the mass chars, then burns and leaves a residue of oxide. On passing dry ammonia gas into the ethereal solution of the chloride a heavy precipitate is formed. This is ammonium chloride and columbium nitride. On washing with water the ammonium chloride is dissolved out, leaving a white residue which reverts on ignition to oxide of columbium, and when boiled

with sodium hydroxide gives off ammoniacal vapors, thus pointing to nitride of columbium, likely Cb_3N_5.

Columbium chloride containing some sulphur monochloride was treated with benzene. The sulphur monochloride dissolved out, while the columbium chloride was decomposed, leaving an insoluble gummy mass. Chloroform dissolved the chloride readily, but the solution seemed to undergo decomposition on warming and evaporating, as the liquid became brown and a brown powder separated. No crystalline product could be procured.

The chloride is also soluble in alcohol. In the cold there is no decomposition. On warming and concentrating the solution acid vapors were given off, due perhaps, as H. Rose has suggested, to the formation of ethyl columbate. That there is no decomposition in dilute solution is shown by the formation of the compound $CbCl_5(C_5H_{11}N)_6$, which was obtained on adding piperidine to the alcoholic solution (*Zeit. anorg. Chem.*, **36**, 100). Other bases, such as aniline, pyridine, etc., gave addition products which were insoluble in the solvent.

The best solvent for columbium chloride is carbon tetrachloride. In this solution reactions should take place, as they do with other chlorides, in aqueous solution; also double chlorides, analogous to the double fluorides, should be formed by bringing together solutions of the chlorides in carbon tetrachloride.

POTASSIUM FLUOXYPERCOLUMBATE.

When potassium columbium oxyfluoride is dissolved in three per cent. hydrogen peroxide the solution acquires a yellow color. When a saturated solution cools a pasty mass of crystals separates. These are very hard to free from mother liquor. When dry they have only a faint yellow tint. On dissolving in water, containing hydrogen peroxide, the solution again becomes yellow in color. The salt obtained in this way is potassium fluoxypercolumbate of the following composition — $K_2CbO_2F_5.H_2O$.

METHOD OF ANALYSIS.

The potassium was determined as sulphate and the columbium as oxide in the usual way, that is, by expelling the fluorine with sulphuric acid, boiling with water, filtering out the insoluble

columbium hydrate and evaporating the filtrate to dryness and weighing the potassium sulphate after ignition.

The oxygen and water were determined in another sample by weighing a portion of the substance in a tube sealed at one end, covering it with a plug of ignited asbestos, connecting with a gas burette and igniting. The oxygen was collected and measured, the tube was reweighed, the loss being water and oxygen. The water was obtained by difference.

Analysis :

0.4004 gram of the salt gave 0.1672 gram of oxide and
0.2196 gram of K_2SO_4

0.4432 gram of the salt lost 0.0470 gram, which contained 17.9 c.c. of oxygen at 24° and under 742 mm. pressure, or 0.0229 gram, the difference — 0.0241 gram — being water.

	Calculated.	Found.
K_2SO_4	54.89	54.84
Oxide	42.28	41.84
O (active)	5.05	5.16
H_2O	5.68	5.44

This salt was obtained and the above composition ascribed to it by Piccini (*Zeit. anorg. Chem.*, **2**, 21). He regarded it as a derivative of percolumbic acid and not an addition product of potassium columbium fluoride and hydrogen peroxide, because the water was lost on heating at 100°, while the oxygen did not escape until the temperature reached 150°.

On crystallizing this salt from concentrated hydrofluoric acid and hydrogen peroxide in the hope of getting a perfluoride large plates were obtained, which were quite yellow in color with a green tint when dry. They did not seem to differ if little or much hydrofluoric acid was used. The crystals taken for analysis were obtained from a solution consisting of one-half hydrofluoric acid, 48 per cent., and one-half hydrogen peroxide, 3 per cent. They were dried between filter paper and promptly weighed out for analysis.

Analysis:

0.7260 gram of salt gave 0.3274 gram of oxide and
0.3982 gram of potassium sulphate.

0.7482 gram of salt lost 0.0784 gram on ignition, i. e., 29.1 c.c. of oxygen at 24° and under 742 mm. pressure, or 0.0374 gram, the difference — 0.0410 gram — being water.

	Calculated.	Found.
K_2SO_4	54.89	54.85
Oxide	42.28	42.34
O (active)	5.05	5.00
H_2O	5.68	5.48

Hence it may be concluded that the salt obtained from strong hydrofluoric acid is the same as that got when hydrofluoric acid is not used.

It would seem impossible to obtain a derivative of percolumbic acid which does not contain oxygen.

The salt separates from solutions containing hydrofluoric acid in large well-formed plates, which may be easily measured. They are much easier to handle than when crystallized from a solution free from acid. The crystals are always greenish yellow in color.

Piccini states that the salt obtained by him had a slight yellow tint, but that this color was completely removed by two recrystallizations from hydrogen peroxide. The salt obtained above was recrystallized six times from hydrogen peroxide containing hydrofluoric acid. The crystals from the last crystallization were fully as highly colored as those which had not been recrystallized. They were then recrystallized twice from hydrogen peroxide containing no acid. The resulting salt was practically colorless, but it dissolved in water and hydrogen peroxide with a yellow color, which was intensified by the addition of hydrofluoric acid and on evaporating again to crystallization the crystals were as highly colored as any obtained previously.

The oxide from the double fluoride, originally used, gave a color equivalent to 0.4 per cent. TiO_2. It was supposed that this color was due entirely to titanium and that the yellow color of the solution and of the crystals of potassium fluoxypercolumbate was also due to this element. To test this supposition 100 grams of the purest potassium columbium oxyfluoride was crystallized twice from strong hydrofluoric acid. The crystals obtained were decomposed with concentrated sulphuric acid, and the hydrate after extraction with water ignited to oxide. The color which this oxide developed in oxalic acid solution with hydrogen peroxide was equivalent

to 0.24 per cent. of its weight of titanic acid. It was now heated in sulphur monochloride and converted into chloride. The latter, together with the excess of monochloride, was collected in a receiver and the sulphur monochloride distilled out in the hope that any titanium tetrachloride present would be expelled with it. The chloride remaining after removing the sulphur monochloride was converted into oxide. It contained titanic oxide equivalent to 0.16 per cent. The oxide was again heated in sulphur monochloride and treated as before. After the second treatment the titanic oxide equivalent was .12 per cent. and the color now developed was different. It was greenish yellow instead of yellow inclining towards red, which is characteristic of titanium. About five grams of the oxide which had passed through this treatment were changed to double fluoride and crystallized from hydrogen peroxide and hydrofluoric acid. Its solution, in hydrogen peroxide, was yellow and its color increased in intensity on adding hydrofluoric acid. The crystals from it were canary yellow with a tint of green, differing in no respect from those previously obtained.

About ten grams of this yellow salt were next dissolved in water and hydrogen peroxide. This solution was distinctly yellow in color. It was divided into two portions. To one portion 0.5 gram of potassium titanium fluoride was added. The color in this portion became considerably deeper, but the excess of color was completely discharged upon adding hydrofluoric acid, the two solutions becoming again identical in color.

Potassium titanium fluoride dissolved in hydrogen peroxide to a deep yellow-colored solution. On cooling crystals were deposited, which were not yellow but colorless when completely free from mother liquor. The addition of hydrofluoric acid to the colored solution completely destroys the color, and in the presence of hydrofluoric acid the salt formed is white, resembling potassium titanium fluoride. When air dried it gives off neither water nor oxygen on ignition.

The only elements which give a distinctive color in acid solution with hydrogen peroxide and which might occur here are titanium, vanadium and molybdenum. Of these the first has been excluded and the second also by reason of the color which it gives (red to rose red). There still remains molybdenum. Its color in an oxalic acid solution with hydrogen peroxide is identical with that

observed in the case of the columbium as free from titanium as it could be obtained. Although the columbium oxide used for these tests had passed through several manipulations which should remove molybdenum, such as, fusion with sodium carbonate and sulphur, changing to chloride with sulphur monochloride and distilling off the more volatile portion, it was thought best to determine how much molybdenum would be required to give a test equal to that obtained from the purest oxide of the columbium at hand. To this end weighed amounts of molybdenum were dissolved in oxalic and sulphuric acids, and the color, developed with hydrogen peroxide, compared with that obtained with a standard titanium solution of hydrogen peroxide.

1. 0.2780 gram of molybdic acid developed a color equivalent to 0.0048 gram TiO_2, or 0.0058 gram of molybdic acid will give a color equal to that given under similar conditions by 0.0001 gram TiO_2.

2. 0.0660 gram of molybdic acid gave a color equal to 0.0015 gram TiO_2, or 0.0044 gram of molybdic acid is equal to 0.0001 gram TiO_2.

The variations in these results is due to the difficulty in matching the different shades as to intensity of color. The average is about right, or 0.0050 gram of molybdic acid is equivalent to 0.0001 gram TiO_2. Calculating on this basis, the best oxide of columbium obtained, which gave a color equivalent to .12 per cent TiO_2, would contain 6 per cent. of MoO_3 if the color was due to the presence of molybdenum, which would be impossible after the treatments through which the oxide has passed. It had been crystallized twice as potassium oxyfluoride, fused with sodium carbonate and sulphur, the tantalum removed, again crystallized as the oxyfluoride of potassium and twice from hydrofluoric as potassium columbium fluoride, then changed to chloride in sulphur monochloride, the sulphur monochloride and the more volatile portions distilled off and rejected, again changed to oxide and this treatment with sulphur monochloride repeated. The final oxide was converted into potassium fluoxypercolumbate and crystallized once from hydrogen peroxide and hydrofluoric acid. This salt was yellow in color, and 0.3540 gram of oxide from it, dissolved in oxalic acid, gave with hydrogen peroxide a color equivalent to 0.000424 gram TiO_2, or .12 per cent. At the most it could not have contained more than a bare trace of oxide of molybdenum.

0.3470 gram of the oxide from the yellow fluoxypercolumbate was dissolved in oxalic acid and chromotropic acid and diluted to 50 c.c. It gave a very slight pink color, about equal in intensity to the color developed in 50 c.c. by .000025 gram TiO_2 in the same amount of oxalic acid on treating with chromotropic acid. This would correspond to less than .01 per cent. of TiO_2 and is likely not very far wrong.

From these experiments it may safely be concluded that the color produced in hydrofluoric acid solution of columbium with hydrogen peroxide is not due to the presence of titanium. Also it is likely that columbium itself gives a distinctive color with hydrogen peroxide, equivalent to from .10 per cent. to .15 per cent. of its weight of TiO_2, yet yellow green instead of straw yellow, as is given by titanium in dilute solutions. Possibly there may still be present some other element. For this careful search will be made.

PREPARATION AND ANALYSIS OF THE YELLOW OXIDE OF COLUMBIUM.

Hydrated oxide of columbium, containing ten grams of oxide, was prepared by decomposing the double fluoride with sulphuric acid, evaporating off the excess of acid and extracting with boiling water. This hydrate was washed repeatedly with boiling water and air dried. It was covered with about 20 c.c. of concentrated hydrochloric acid and brought to boiling for several minutes, until all of the lumps had thoroughly disintegrated, when it was diluted to about three times its original volume with water. All but a few particles were dissolved. This solution was filtered and an equal volume of three per cent. hydrogen peroxide added. It became yellow and after a few minutes a yellow precipitate appeared. The solution was allowed to stand over night. The precipitate was then filtered out, washed with cold water, in which it was insoluble, and air dried.

Under the above conditions about one quarter of the oxide in solution was precipitated by the hydrogen peroxide. If the remainder of the oxide in solution were recovered and dissolved in hydrochloric acid, as before, a fresh portion of it could be precipitated on adding hydrogen peroxide. The air-dried precipitate lost oxygen and water on ignition and regained its white color.

As the precipitation of the columbium was only partial it was best to be certain of the identity of the portion precipitated. To this end 2.5 grams of the yellow oxide were obtained, ignited to remove the excess of oxygen, and changed to the potassium double fluoride. This analyzed as follows:

0.6822 gram of the salt gave 0.3026 gram of oxide and 0.3966 gram of K_2SO_4

	Calculated.	Found.
Oxide	44.52	44.36
K_2SO_4	57.81	58.14

Hence the compound obtained is a derivative of columbium.

Columbium is not precipitated from the solution remaining after the yellow precipitate has been filtered out, by an excess of ammonium hydroxide, until the hydrogen peroxide in the solution has been destroyed.

Analysis of the yellow precipitate:

0.1917 gram of sample gave 0.1298 gram of Cb_2O_5.

0.2556 gram of sample gave 7.8 c.c. of oxygen at 22° and under 741 mm. pressure, equal to 0.0101 gram.

	Percentage.	Ratio.
Cb_2O_5	67.71	1.000
O (active)	3.95	0.984
H_2O (difference)	28.34	6.240
	100.00	

This corresponds to $Cb(OH)_6$, or to $Cb_2O_5H_2O_25H_2O$.

Melikoff and Pissarjewsky (*Zeit. anorg. Chem.*, **20**, 340) obtained a percolumbic acid of the formula $HCbO_4 + nH_2O$, by heating columbium hydrate with 30 per cent. hydrogen peroxide on a water bath. They also obtained it by adding sulphuric acid to a solution of sodium percolumbate, dialyzing out the excess of sulphuric acid and the potassium sulphate, then evaporating the clear yellow solution to dryness on a water bath. They describe it as a yellow amorphous powder, insoluble in water.

The color of these higher oxides seems characteristic of columbium and is certainly not due to the presence of titanium. The hydrate obtained by Melikoff and Pissarjewsky contained twice as much active oxygen, in proportion to the columbium, as did the hydrate obtained during this investigation.

DIFFERENCE IN SOLUBILITY OF DOUBLE FLUORIDES.

It is of interest to note that the solubility of potassium titanium fluoride is increased upon the addition of hydrogen peroxide, while that of the potassium columbium oxyfluoride is decreased. In hydrofluoric acid this order is reversed, the columbium salt becoming more soluble and the titanium salt less soluble. This suggests alternating these solvents in the crystallization of columbium and potassium double fluorides as one of the best means for removing titanium.

Recrystallization from hydrofluoric acid in the form of K_2CbF_7 will remove tin and probably also tungsten from impure potassium columbium oxyfluoride. Two recrystallizations from that solvent are sufficient to give an oxide, the ignition of which in a platinum crucible gave no stain on the crucible. If partially dried oxide wrapped in the filter paper be ignited directly in a platinum crucible the presence of a stain on the crucible after removing the oxide will be a very delicate test for tin. It is likely that when tin is removed by crystallization tungsten is also, if they are present in about equal amounts and in such cases where the total amount is very small. The procedure would remove the necessity for the tedious sodium carbonate and sulphur fusions used in this work.

BEHAVIOR WITH PRECIPITANTS.

Pennington (*Jour. Amer. Chem. Soc.*, 18, 38) noted that disodium hydrogen phosphate gave no precipitate in a solution of potassium columbium oxyfluoride, while it completely precipitated titanium from a solution of its double fluoride. This was studied briefly in order to determine if it might not serve as a quantitative separation of columbium from titanium. It was found that when the reagent was added to a solution containing a large excess of columbium and only a little titanium no precipitate was produced even on prolonged boiling. If the amount of titanium was increased slightly both the titanium and the columbium were completely precipitated by the disodium hydrogen phosphate. This reagent, therefore, does not separate the two elements.

Geisow found that an alkaline formoxime solution precipitated zirconium and titanium, but did not precipitate columbium.

Formoxime, or its polymerization product, was prepared by bringing together solutions of the calculated quantities of formal-

dehyde, sodium carbonate, and hydroxylamine hydrochloride. The resulting solution gave no precipitate when added to a solution of titanium as double fluoride, zirconium as double fluoride, or to a solution of columbium double fluoride. Further, after the addition of the formoxime solution, ammonium hydroxide failed to give a precipitate with any of the solutions noted above. It did, however, give a precipitate with tantalum double fluoride, but this was only partial.

The statement of Geisow that titanium and zirconium can be separated from columbium by means of an alkaline formoxime solution was not verified. The precipitation with tantalum is only partial, and not complete as stated by him.

It was noted (*Jour. Amer. Chem. Soc.*, **26**, 1248) that potassium iodate gave a complete precipitation in a solution of potassium titanium fluoride, and no precipitate with a solution of columbium double fluoride. Potassium iodate, free from periodate, was prepared, and it was found to give no precipitate with either columbium or titanium, except in acid solution, when both were precipitated. A solution of a periodate was not tried.

UNIVERSITY OF PENNSYLVANIA.

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1905

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1. The candidate shall, on or before November 1, 1905, deliver free of postage or other charges, his discovery, invention or improvement, addressed to the President of the American Philosophical Society, No. 104 South Fifth Street, Philadelphia, U. S. A., and shall distinguish his performance by some motto, device, or other signature. With his discovery, invention, or improvement, he shall also send a sealed letter containing the same motto, device, or other signature, and subscribed with the real name and place of residence of the author.

2. Persons of any nation, sect or denomination whatever, shall be admitted as candidates for this premium.

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4. The candidate shall communicate his discovery, invention or improvement, either in the English, French, German, or Latin language.

5. A full account of the crowned subject shall be published by the Society, as soon as may be after the adjudication, either in a separate publication, or in the next succeeding volume of their Transactions, or in both.

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PROCEEDINGS

OF THE

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PHILADELPHIA

THE AMERICAN PHILOSOPHICAL SOCIETY

104 SOUTH FIFTH STREET

1906

GENERAL MEETING—1906

The next General Meeting of the Society will be held on April 17-20, 1906; beginning on the evening of Tuesday, April 17.

Wednesday, April 18, will be devoted to the presentation and discussion of scientific papers, and Thursday, 19 and Friday, 20, to the ceremonies connected with the celebration of the 200th Anniversary of the Birth of Benjamin Franklin.

Members desiring to present papers on subjects of science at the General Meeting are requested to communicate with the Secretaries at once.

CORRIGENDUM

In No. 179 the volume number should be corrected to read Vol. XLIV.

Pages 1-4, including a title page containing the correct volume number, to be substituted for like pages in No. 179, are inserted at the end of this volume.

Members who have not as yet sent their photographs to the Society will confer a favor by so doing; cabinet size preferred.

It is requested that all correspondence be addressed

To the Secretaries of the

AMERICAN PHILOSOPHICAL SOCIETY

104 South Fifth Street

Philadelphia, U. S. A.

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VOL. XLIV. AUGUST–DECEMBER, 1905. No. 181.

A STUDY OF THE ANATOMY OF PHALÆNOPTILUS, RIDGWAY.[1]

BY MARGARET E. MARSHALL.

(PLATES IV, V AND VI.)

(*Received June 19, 1905.*)

INTRODUCTION.

The present paper is a contribution to the knowledge of *Phalænoptilus nuttalli nitidus* (Brewster), the Poorwill, and presents an account of the alimentary, respiratory and urogenital organs, the central nervous system and all the muscles of the anterior extremity and those of the thigh.

As generally defined now the Caprimulgi include the three families of Steatornithidæ, Podargidæ and Caprimulgidæ. In regard to their distribution Fürbringer (1888) says that the Caprimulgidæ represent the largest family (some 100 species) and with almost cosmopolitan distribution (exclusive of New Zealand, the pacific subregion and the southern part of South America); the Steatornithidæ, represented by a single species, occur in caves in the tropical Andean region and the West Indies; the Podargidæ consisting of about 20 species inhabit the oriental region, particularly New Holland and Papuasia. Of the Caprimulgidæ the following genera occur in North America: *Antrostomus*, *Phalænop-*

[1] Contributions from the Zoölogical Laboratory of the University of Texas, No. 68.

tilus, *Nyctidromus* and *Chordeiles*. Of these genera *Phalænoptilus* extends from Guatemala northward in the western United States nearly to British Columbia, and is represented by three geographical races of one species. This genus was first established by Ridgway (1880), and is defined as follows by Coues (1903): "Nostrils tubular, cylindrical, opening forward and outward. Rictal bristles immense, but simple. Tarsus naked except just on the joint above (as in *Nyctidromus*), as long as middle toe without claw. Tail square, much shorter than the rounded wings, which fold nearly to its end." No anatomical description of this genus has heretofore appeared so far as the writer knows.

The aim of this study is the interesting question of the homologies of the Caprimulgi. Fürbringer (*l. c.*) discusses at length the varying views on their relationship to Ardeidæ, Glareolidæ, Strigidæ, Cuculidæ, Galbulidæ, Trogonidæ, Coraciidæ, Leptosomidæ, Todidæ, Momotidæ, Coliidæ, Cypselidæ, Trochilidæ and Passeres (*Eurylæmus*, *Hirundo*), and sums up his position in these words: "On the ground of the given comparisons, I am inclined to regard the Caprimulgidæ, Steatornithidæ and Podargidæ as independent but closely related families, and as united under Caprimulgi; they stand in remarkable genealogical relations in the first line to the Striges and Coraciæ and in the second to the Trogonidæ and Cypselidæ, while the relation to the other families coming in question is less near and direct." Gadow (1891), considers the Caprimulgi as related ancestrally to the Striges and laterally first with the Coraciæ and second with the Cypseli. It soon became apparent to the writer that this problem of affinities could not be settled by the investigation of a single genus. Accordingly this paper is intended to be the first of a series dealing with these birds, and is essentially descriptive, general theoretical considerations being postponed until personal studies have been made upon other forms. Because there was not time to describe the whole anatomy it seemed advisable to omit the osteology, since most of the previous work has been done upon the skeleton.

Special anatomical monographs upon such species of birds are so few, and yet so much needed, that it is hoped this one may be of some service to comparative anatomists.

The material used consisted of two entire adult females secured by Dr. Thos. H. Montgomery, Jr., in the month of June, 1904, in

Brewster County, Texas, one preserved in alcohol and the other in formalin.

This work has been done entirely under the direction of Dr. Montgomery, and I am very much indebted to him for many helpful suggestions, and for his unfailing sympathy and encouragement during the preparation of this memoir.

I. Alimentary Tract.

This bird is remarkable for its enormous *mouth*. Arranged in a regular series along the upper border of the gape there are on each side of the mouth eight long vibrissæ, modified feathers.

The *tongue* (*T*, Pl. IV., Fig. 10), is slender and pointed. Posteriorly it is bifid and fimbriated. The hyoid bone (Figs. 1 and 10) consists of the following parts: os entglossum (*Ent. g.*), basihyal (*Bas. h.*), urohyal (*Ur. h.*), basibranchial (*Bas. b.*), ceratobranchial (*Cer. b.*), and epibranchial (*Ep. b.*). The entglossum is entirely cartilaginous and is bifurcated in the posterior half, the forks articulating in each side with the basihyal. The osseous basihyal is a solid piece broadening posteriorly, reaching its greatest width where the basibranchials come off. It then narrows immediately into the urohyal which has the same structure except for the cartilaginous tip. The urohyal is about twice the length of the basihyal. The "horns" of the tongue bone are also of cartilage. The basal segments, the basi-branchials, are about one half the entire length of the horn; the articulating joints, the ceratobranchials, are a little more than one fourth the length of the horn; the last members, the epibranchials, are about one fourth the length of the horn.

The wide *pharynx* (*Pha.*, Pl. IV, Fig. 10) is succeeded by the œsophagus (*Œs.*, Fig. 10) which is immediately slightly dilated. There is no crop. Behind its anterior dilation the œsophagus gradually narrows until at its posterior end the diameter is little more than half the diameter of its anterior portion.

The *œsophagus* passes over into the proventriculus (*Prov.*, Pl. IV, Figs. 9, 10, 15), which opens into the anterior end of the gizzard (*Giz.*, Figs. 9, 10, 15) somewhat to the right of the midline. The gizzard is overlain anteriorly by the liver lobes, and extends posteriorly to the region of the cloaca.

The *intestine* (*Int.*, Pl. IV, Figs. 9, 15), arises from the right

side of the gizzard at the base of the proventriculus, and consists of four distinct divisions:

1. The *duodenum* (*Duo.*, Figs. 6, 9, 15) makes up the entire first loop. It extends from the pylorus almost to the posterior end of the stomach. It then bends anteriorly, and at the edge of the right liver lobe passes over into the small intestine. The duodenum is about 43 mm. in length.

2. The *small intestine* (Figs. 12, 15) lies between the duodenum and the insertion of the cæca. It measures about 85 mm.

3. The *terminal intestine* (Figs. 12, 15) extends from the insertion of the cæca to the anus and is very short. Anteriorly the diameter is very small but posteriorly it is dilated at the cloaca. Its length is about 18 mm. Thus the entire length of the main intestine from pylorus to anus is 146 mm. The intestine consists of three closed loops of which the duodenal is the first in course. The ascending branch of the third loop and the following portion of the small intestine are covered by the first and second loops. The descending branches of the second and third loops are to the left of their respective ascending branches. The intestinal arrangement agrees with the iso-orthocœl type of intestine as defined by Gadow (*l. c.*).

4. Two *cæca* (*Cæ.*, Figs. 12, 15) are present. They are quiet long and the terminal half of each almost equals the small intestine in size. At about one third the length of the cæca from their insertion there is on each a constriction, and at this point the diameter is less than in any part of the alimentary tract. From tip to insertion the cæca measure about 35 mm.

Filling the duodenal loop is a pale, slender organ, the *pancreas* (*Pan.*, Figs. 6, 9, 15). It consists of two branches, the main branch occupying the position mentioned. Extending beyond the edge of the ascending branch of the duodenum is the smaller division. The pancreas has two ducts (*Pan. d.*), both coming off on the dorsal surface. The larger duct, which comes from the main portion, arises proximal to the branching off of the smaller part, and running anteriorly close to the descending part of the loop of the duodenum enters its ascending branch just about where it begins to curve along the right liver lobe. The small duct comes from the smaller division on its inner edge at a point about one third the length of that division from its anterior end.

Only the merest rudiment of a spleen (*Spl.*, Pl. I, Fig. 9) is present. It is a small, whitish, almost round body lying under the right lobe of the liver close beside the gall-bladder.

The *liver* (*Liv.*, Pl. IV, Figs. 9, 10, 15) consists of two smooth lobes, the right being somewhat the larger. The lobes are connected anteriorly. They extend from the heart back over the stomach for about one half its length. From the right lobe just above the duodenum comes off the greenish colored gall-bladder (*G. bl.*, Fig. 9). The figure exhibiting the pancreatic ducts shows also two others, one situated between the ducts of the pancreas and another anterior to the smaller pancreatic opening. These I have taken to be the liver ducts (*Liv. d.*). They could not be traced further on account of the mutilated condition of the bird.

The *salivary glands* were not found.

II. Respiratory Organs.

The *glottis* is an oval aperture situated behind the root of the tongue leading into the trachea. Immediately posterior to the glottis is a bilobed fimbriated fold of the mucous membrane.

Ventrally, the *larynx* (*Lar.*, Pl. IV, Fig. 10) presents two rather flat, somewhat triangular, cartilages, the thyroids, which terminate anteriorly at the posterior border of the basihyal. The thyroids are narrowed in front but not pointed. The two cartilages are divided anteriorly by the urohyal which extends almost to their base.

The length of the *trachea* (*Tra.*, Pl. IV, Fig. 10) from the larynx to the branching of the bronchii is about 5 cm. The rings of the trachea, about seventy-seven in number, are complete with two exceptions; the anterior dorsal has its dorsal edges fused with the thyoid, and the rings of the posterior dorsal surface are incomplete. There are three modifications of these rings on the ventral surface. Succeeding the base of the larynx there are four simple rings. The next three are slightly constricted in the middle. From this point down to where the trachea begins to broaden out before passing between the forks of the furcula, the rings are interlaced, trowel fashion. Between the last of these rings and the branching of the bronchii we find a repetition of the condition first described, only the rings are broader and stronger.

The trachea has only two sets of muscles (Pl. IV, Figs. 7, 8, 10).

One pair comes off on each side from the last tracheal ring, and continues anteriorly almost to the larynx, at which point it spreads out fan-like, the delicate fibers being attached to the upper end of the windpipe; this muscle is the *trachealis lateralis* (*Tr. Lat.*), named according to the description given by Shufeldt (1890),[1] though it does not agree in all points with it; there is a partial agreement with Gadow's (*l. c.*) *m. tracheo-bronchialis.* The second pair of muscles is much stronger but shorter than the last described, and the origin is more ventral. They arise from the trachea on each side between the sixth and the tenth rings, counting forward from the last tracheal ring. The muscles become gradually smaller as they approach the insertion which is about the midpoint of the proximal part of the first rib articulating with the sternum. This is the *m. sterno-trachealis* (*St. tr.*), though it does not agree in all points with Gadow's (*l. c.*) description of the muscle of the same name.

The *syrinx* (Pl. IV, Figs. 7, 8) is tracheo-bronchial. On the ventral surface (Fig. 7) the last tracheal ring is directed downward forming with the one above an almost triangular space, of which the preceding tracheal ring is the base. Corresponding to the last tracheal ring on the left side there are two on the right, separated by a small space. These rings and the first bronchial rings are fused at their inner extremities to a small membrane at the base of which the bronchii separate. This membrane is stronger than that between the rings, and is of a yellowish color. The second bronchial ring bifurcates at its inner extremity, the lower branch fusing with the following ring, thus causing it to be much enlarged at its inner termination. Each bronchus is bounded on its inner surface by a cartilaginous rod, and this rod closes the almost circular space embraced partially by the above mentioned bifurcation. The second, third and fourth rings are larger than any of the others, less flexible, and of a yellowish color.

The *membrana tympaniformis externa* (*Tym. ex.*), is double in this bird. It is bounded by the second and fourth rings, and crossed in the middle by the third. This third ring is larger than the other two. The fourth at its inner extremity loses the yellowish color and for this reason seems shorter than it really is. In all, the number of rings in the right bronchus is fourteen and in the left twelve. This may be an individual variation.

[1] Myology of the Raven, Philadelphia, 1890.

On the dorsal surface (Fig. 8) we find a condition quite different from that shown on the ventral. All of the bronchial rings are incomplete dorsally. Counting forward from the last tracheal ring, we find between the third and sixth rings a cartilaginous bridge situated in the mid-line of the trachea. It is like the cartilage of the rings, and is, probably, a fusion of the dorsal ends of the fifth, fourth and part of the third rings with an extension to the sixth. This bridge broadens posteriorly, and at the third ring from the last divides, the branches terminating at the last tracheal ring. Down the center of the pyramidal-shaped area enclosed by this fork passes a yellowish rod which is quite resistant to the needle and is probably bony. It extends beyond the ends of the fork. This pyramidal area is bounded posteriorly by a cartilaginous ridge which bends back in the mid-line and gradually fades out on the side as the bronchial half-rings are reached, forming at this point the upper boundary of the *membrana tympaniformis interna* (*Tym. in.*). Below this is another ridge of like structure which forms the lower boundary of the inner tympaniformis.

Between the dorsal ends of the third, fourth, and fifth half rings there is a round whitish body covered irregularly with yellowish brown spots. About half way between the ends of the next four half rings there is, in the right tympaniformis, a white club-shaped body (Pl. I, Fig. 8, *x*). The membrane is much thinner around its edges than elsewhere. Strands of a dark pigment substance are seen around the edges and over the inner surface of this object when the bronchus is opened. A similar structure has evidently been lost from the left tympaniformis, judging from the appearance of the membrane. All of these bodies are probably bits of cartilage.

III. Female Urogenital Organs (Pl. IV, Fig. 11).

The left ovary (*Ov.*) is situated anterior to the left kidney. The oviduct (*L. ovi*), a very much convoluted tube, terminates anteriorly in an *infundibulum* (*Inf.*) facing the left ovary. It lies to the left of the pelvic cavity and opens posteriorly into the left side of the cloaca just behind the ureter. The right ovary is absent, but a very much reduced oviduct (*R. ovi.*) is present. The infundibulum is readily made out, and slight convolutions of the duct are to be observed.

The fused *kidneys* (*K.*) extend from the lungs to the pelvic cavity. The right kidney, slightly larger than the left, consists of three lobes, the middle one being the smallest. The two lobes of the left kidney are of about equal size. The *ureters* (*Ur.*) pass posteriorly to the cloaca which they enter on its dorsal surface median to the oviducts.

IV. Central Nervous System (Pl. I, Figs. 2, 3; Pl. II, Fig. 16*a*).

The brain of this bird is notably small as compared with the size of the head. Its length much exceeds its breadth, resembling in this respect the brain of a lizard. The large optic lobes (*Op. l.*) are only partially covered by the cerebral hemispheres. The cerebellum (*Cb.*), which is comparatively large, covers the medulla oblongata (*Med.*) and on each side of it a flocculus (*Flo.*) is found. The greatest length of the cerebrum (*Cere.*) is about 8 mm., its width 9.5 mm. The longest measurement of the cerebellum is approximately 6 mm., its breadth above the flocculi 5 mm. The uncovered portion of the optic lobes measures from dorsal to ventral surface about 5.5 mm., anterior to posterior border 3 mm. No drawings or measurements of the ventral surface of the brain could be made on account of its torn condition.

The *spinal cord* (*Sp.*), is marked by two important swellings; one in the cervical region known as the *brachial plexus* (*Br. u.*) (Pl. II, Fig. 16*a*), and one in the posterior region as the *sacral plexus*. Anterior to the brachial plexus the cord is larger than it is between this plexus and the succeeding one. The swelling which indicates the branchial plexus begins at the tenth nerve and terminates with the thirteenth. Three nerves take part in the formation of this plexus, the eleventh, twelfth and thirteenth. The second or middle nerve is the largest of the three, the third the smallest. Soon after leaving the cord the second nerve bifurcates, one branch going to each of the other two and all intimately related. The posterior part of the spinal cord was too badly broken for the nerves of that region to be made out.

V. Sense Organs (Pl. IV, Figs. 2, 4, 5).

The *nostrils* (*Nos.*) are tubular and cylindrical, opening forward and outward. Vibrissæ, very much shorter and more delicate than those around the gape, are observed about the nostrils. These

are arranged in a somewhat circular fashion just posterior to the external opening. On each side of the median ridge of the palate is a long, narrow slit bounded by fimbriated folds of mucous membrane, the internal nares.

The pecten of the eye (Figs. 4, 5) consists of four folds. It measures in height about 2 mm., and its basal breadth is about 1.5 mm. Like the choroid coat it is heavily pigmented.

VI. Myology.

Only muscles of the extremities have been considered, and in naming them the terminology of Gadow (*l. c.*) has been followed as strictly as possible. There are, however, many deviations from his definitions.

1. *Anterior Extremity.*

Here are described all the muscles of the wing proper, also all coming from the shoulder girdle, ribs and vertebræ and inserting upon the wing, also all the muscles inserting on the scapula and coracoid. The metacarpals named by Gadow (*l. c.*) I, II and III are herein termed II, III and IV, for recent embryological investigation show the first and fifth to be the ones lost.

A. *Pectoral Muscles.*

1. *M. pectoralis.* The *pars propatagialis* and *pars abdominalis* are absent.

Pars thoracica (*Pect.*, Pl. V, Fig. 24; Pl. VI, Fig. 25). This is the large superficial muscle of the breast, and covers the other breast muscles. It has an extensive origin, coming from the clavicle and the membrane between that bone and the sternum; from the surface of the keel, the upper half; the posterior border of the sternum; and the posterior lateral portion of the breast bone.

It has two points of insertion, both of which are on the humerus. The short strong tendon which terminates on the ventral projection of the humerus, just anterior to the biceps, is the posterior insertion. The fibers of the anterior portion converge and pass obliquely to the dorsal crest of the humerus and are there attached fleshily.

2. *M. supracoracoideus* (*Sup. cor.*, Pl. VI, Figs. 25, 30). This is a double-feathered muscle arising from that portion of the coraco-clavicular membrane not occupied by the muscle just described,

from about the lower half of the keel and from that portion of the body of the sternum not appropriated by the above muscle. The fibers converge to a line which is dorsal to the mid-line, passing over into a strong flat tendon that bends around to the inner surface of the coracoid. The tendon goes through the foramen triosseum and is attached to the humerus on its dorsal projection.

3. *Coraco-brachialis posterior* (*Cor. br. p.*, Pl. VI, Figs. 25, 26, 30). When the *m. pectoralis* is turned back this small muscle is seen extending out from under the supracoracoideus. It arises from the dorsal proximal half of the border of the coracoid. The fibers converge to form a short strong tendon which is attached to the antero-ventral margin of the humerus just anterior to the pneumatic foramen.

B. *Other trunk muscles inserting on wing, scapula and coracoid.*

1. *M. deltoideus major* (Pl. V, Figs. 16, 22). This muscle consists of an anterior and posterior portion. The delicate anterior part (*Del. a.*) arises fleshily from the inner surface of the clavicle and the neighboring portions of the scapula. It emerges from the foramen triosseum, crosses the tendon of the *m. supracoracoideus*, runs entirely around the projection to which the tendon of the muscle is attached, and makes a fleshy insertion at the base of the anterior border of the humeral crest.

The large posterior portion (*Del. p.*) springs from the dorsal border of the clavicle and adjoining dorsal surface of the scapula. It passes obliquely downward and is inserted fleshily on the humeral crest and along the shaft of the humerus for about one half its length. This differs somewhat from Gadow's description.

2. *M. deltoideus minor*. This muscle could not be made out, therefore is probably absent.

3. *M. latissimus dorsi* (Pl. V, Figs. 17, 22; Pl. VI, Fig. 26). This is the most superficial muscle of the back, and is revealed by the removal of the skin. It consists of two portions, a very thin anterior layer and a much larger and stronger posterior muscle bundle.

The anterior portion (*Lat. d. a.*) arises from the spine of the last cervical vertebra and from the spines of the two following dorsal vertebræ. The fibers pass in a transverse direction over the scapula, converging somewhat after crossing it, and diverge as they

approach the humerus. The muscle inserts upon the humerus between the pars scapuli-cubitalis and the pars humero-cubitalis near the lower point of the humeral crest.

The posterior part (*Lat. d. p.*) comes from the last dorsal vertebra and the anterior rim of the ilium. The fibers converge rapidly as they pass anteriorly, and find their insertion on the humerus beneath the anterior border of the above.

4. *M. rhomboideus superficialis* (*Rh. s.*, Pl. V, Figs. 17, 22). This flat muscle comes from the last two cervical vertebræ and the following dorsal vertebræ. It is inserted fleshily on the dorsal part of the furcula and on the entire dorsal border of the scapula.

5. *M. rhomboideus profundus* (*Rh. p.*, Pl. IV, Fig. 17). This muscle is covered by the last mentioned muscle and by the posterior portion of the latissimus dorsi. It springs fleshily from the last cervical and first dorsal vertebræ. The outward directed fibers find a fleshy insertion on the posterior half of the dorso-median border of the scapula, the insertion being continued down to the posterior tip of this bone.

6. *M. scapuli-humeralis anterior.* This muscle is absent.

7. *M. scapuli-humeralis posterior* (*Sc. hum. p.*, Pl. V, Figs. 17, 22; Pl. III, Fig. 26). This large, somewhat rhomboidal-shaped muscle comes from the outer surface of the posterior two thirds of the scapula. It is covered by both portions of the latissimus dorsi. Its fibers are directed forward and downward, converging rapidly to form a small, round bundle which is attached within the foramen pneumaticum.

8. *M. subscapularis* (*S. sc.*, Pl. VI, Fig. 26). This muscle becomes visible after the removal of the m. scapuli-humeralis posterior and m. scapuli-cubitalis. Anteriorly it comes from the dorsal surface of the scapula just posterior to the origin of the scapuli-cubitalis, and posteriorly from the lower border of the same bone where it is overlain by the scapuli-humeralis posterior. In its middle portion it is divided into two parts by the anterior m. serratus superficialis, the inner division, subscapularis internus, coming from the ventral surface of the scapula. The outer portion is the subscapularis externus.

9. *M. serratus superficialis* (Pl. VI, Fig. 26) is made up of two parts. The smaller anterior division (*Ser. s. a.*) comes from the last cervical rib and its process uncinatus. The fibers are directed upward

and forward. The muscle terminates tendinously on the ventral border of the scapula. It divides the subscapularis.

The large posterior division (*Ser. sp.*) springs with four scallops or teeth form the second and third dorsal ribs, just below the processes of these ribs. The fibers of these closely-related bundles are directed upward and forward. The most posterior bundle is inserted on the posterior tip of the scapula. The others do not reach the scapula but terminate on the ribs and the membrane connecting them in this region.

10. *M. serratus profundus* (*Ser. p.*, Pl. VI, Fig. 26), occupies a more dorsal position than the last mentioned muscle, and is exposed by the removal of the m. scapuli-humeralis posterior. The edges of the two thin portions composing it overlap. The dorsal bundle comes from the free cervical rib at the outer end of the vertebral projection. The lower bundle arises from the last cervical rib and from the membrane connecting this and the preceding rib. Both bundles are inserted on the posterior median border of the scapula.

11. *M. sterno-coracoideus* (*St. co.*, Pl. VI, Fig. 26) is covered at its origin by the abdominal muscles. It arises tendinously from the first, second and third sternal ribs. This small muscle passes obliquely to the lateral projection of the sternum below the coracoid.

12. *M. subcoracoideus* (*Sub. co.*, Pl. VI, Fig. 26). This delicate fusiform muscle is revealed by the separation of the scapula and coracoid. It springs tendinously from the inner anterior border of the coracoid about one third the length of that bone from its distal end. It is inserted on the humerus proximal to the coraco-brachialis posterior. The fibers of this muscle are closely associated with those of the subscapularis. It differs considerably from Gadow's description.

C. *Muscles restricted to the wing.*

1. *M. propatagialis, pars propatagialis musculi deltoidei* (*Pro.*). This includes both the long and short tendons, the other parts being absent. It arises fleshily from the dorsal end of the clavicle and from the neighboring portions of both coracoid and scapula. It is a flat muscle, about 14 mm. long and 5 mm. broad. At its distal end it tapers off into two tendons, the upper and more deli-

cate being the m. propatagialis longus the lower and stronger m. propatagialis brevis.

a. M. propatagialis longus (*P. pat. l.*, Pl. V, Figs. 22, 24). The tendon of this muscle runs along the anterior margin of the patagium, with which membrane it is intimately connected. Thence it continues as a very delicate tendon to the distal end of the radius. It becomes flattened as it passes over the os radiale, and continues so to its insertion. The flattened tendon passes to the ventral side of the os magnum along its base, and is inserted on the posterior proximal projection of the pollex digit. From this point a pyramidal-shaped tendon with its apex on the pollex-digit extends down to the third metacarpal.

b. M. propatagialis brevis (*P. pat. b.*, Pl. V, Figs. 22, 23) is very complex in this bird. The tendon is larger than the longus and flattened. It continues distally to the m. extensor metacarpi ulnaris (radialis?) where it bifurcates, about 5 mm. from the distal end of the humerus. The longer branch runs back with the m. extensor metacarpi ulnaris (radialis?) to become inserted on the humerus just distal to this muscle, and at the base of the tubercle of the external condyle of the humerus. The shorter one continues distally about 2 mm., then passes back obliquely to the m. extensor digitorum communis and here it bifurcates, the proximal short branch running back with the above muscle to insert itself on the tubercle above the external condyle of the humerus and above the origin of the m. ectepicondylo-radialis. The distal extending branch becomes flattened at its insertion, which is at the base of the styloid process of the radius on its ulnar side, near the m. extensor pollicis longus and covered by it. From the second bifurcation comes off a broad band which passes directly across to the ulna and is inserted on that bone about 7 mm. or 8 mm. from its proximal end.

2. The *metapatagium* was torn away, so I can say nothing about the *m. metapatagialis*.

3. *M. biceps brachii, pars propatagialis* (*Bi.*, Pl. VI, Figs. 20, 27; Pl. II, Fig. 24). This large muscle lies on the anterior surface of the forearm, and arises as two heads. The long head comes from the anterior end of the coracoid as a strong, flat tendon. The short head passes immediately into a stout muscle. The two posteriorly unite to form a fusiform muscle which inserts at the elbow

joint, the more delicate portion of the split tendon being attached to the radius on its inner surface, the other portion to the ulna at the base of the m. flexor digitorum profundus and dorsal to the m. brachialis inferior.

4. *M. brachialis inferior* (*Br. inf.*, Pl. V, Fig. 24). This trapezoid-shaped muscle arises fleshily from the distal end of the humerus, and from its inner surface interior to the origin of the m. extensor metacarpi ulnaris (radialis?). It crosses to the ulna and is inserted on that bone beyond the elbow joint and between the separated portions of the m. flexor digitorum profundus.

5. *M. triceps cubiti.* This muscle consists of two parts, one long head and two short ones.

a. Pars scapuli-cubitalis (*Pars. sc. cub.*, Pl. V, Figs. 16, 17, 22; Pl. III, Fig. 29). This one arises from the neck of the scapula, posterior to the scapular projection which forms part of the glenoid fossa. It passes obliquely across the humerus above the insertion of the latissimus dorsi, continues down the dorsal posterior side of the humerus and near its distal end comes off in a strong flat tendon which is inserted on the rim of the dorsal proximal process of the ulna.

b. Pars humero-cubitalis (*Pars. hu. cub.*, Pl. V, Fig. 24; Pl. IV, Fig. 28) arises by two heads, the inner comes from within the rim of the humeral head, while the stronger has its origin on the outer aspect of the head of the humerus, and from about its proximal quarter. This part ends in a tendon and a broad aponeurosis inserted on the proximal edge of the olecranon process of the ulna, and the intervening space between this process and the insertion of the scapuli cubitalis.

6. *Mm. entepicondylo-antibrachiales.*

a. Mm. entepicondylo-radiales.

(1) *Pronator sublimis* (*Pron. s.*, Pl. V, Fig. 24). This is the most superficial muscle of the inner arm. It springs tendinously from above the internal condyle of the humerus, and interior to the origin of the brachialis inferior. It passes obliquely across the interosseus space to become inserted on the ventral side of the radius for about one third its proximal length.

(2) *Pronator profundus.* This muscle is smaller than the sublimis, and is covered for nearly its entire length by the superficial muscles. It arises from the lower edge of the internal condyle of the

humerus, and is almost concealed at its origin by the strong tendons of the flexor digitorum sublimis. It is split in two by the extensor indicis longus. The fibers of the upper half pass obliquely over to the radius and are inserted on that bone under the pronator sublimis, extending about as far distally as that muscle. The lower half bends under the m. extensor indicis longus and is inserted on the radius in a position corresponding to the upper half. This muscle is not shown in the drawings.

b. M. entepicondylo-ulnaris is absent in this bird.

7. *M. ectepicondylo-ulnaris* (*Ect. u.*, Pl. V, Fig. 19) arises by a strong tendon from the posterior projection of the external condyle of the humerus below the m. extensor digitorum communis, and is covered by the tendon of the m. extensor carpi-ulnaris (radialis?). It passes over to the anterior surface of the ulna, and is there inserted fleshily for fully two thirds the length of that bone.

8. *M. ectepicondylo-radialis* (*Ect. r.*, Pl. V, Fig. 19). This muscle arises from the posterior projection of the external condyle of the humerus, below the origin of the m. extensor digitorum communis and below the insertion of the second forward directed branch of the m. propatagialis brevis. It passes directly over to the proximal end of the radius and is inserted fleshily along its dorsal surface for about one third its length.

9. *M. flexor carpi ulnaris* (*F. carp. ul.*, Pl. V, Fig. 24). This is the largest muscle of the forearm. It arises by a strong, flat tendon from the posterior border of the external condyle of the humerus. It is held in place by a ligament which passes from the condyle over and under the tendon to the base of the olecranon process of the ulna, thus forming a loop. The muscle runs along the ventral surface of the ulna and at about the middle of that bone separates into two tendons. Both continue distally to become inserted on the outer border of the os ulnare, the more delicate on the lower edge.

10. *M. ulni metacarpalis ventralis* (*Ul. met. v.*, Pl. V, Fig. 24). This muscle arises fleshily from about the middle three fifths of the ventral and posterior surface of the ulna, and is broadest at the distal end immediately before passing over into the tendon which crosses in front of the os radiale, to the surface of the third metacarpal and is inserted on its dorsal proximal projection. It is covered by the tendons of other muscles which find their insertion in

this region. The distal portion of this tendon with that of the m. flexor digitorum is held in place by a delicate ligament extending from the distant ventral border of the radius to the ventral projection on the third metacarpal above the os carpi ulnare.

11. *M. ulni metacarpalis dorsalis* (*Ul. met. d.*, Pl. V, Fig. 24), arises by a short strong tendon from the dorsal distal end of the ulna at the base of the external condyle. The tendon bends around the condyle to its posterior border where it swells rapidly into a thick muscle. The greater part of the muscle is inserted fleshily on the posterior border of the fourth metacarpal. A small part of the muscle terminates distally in a broad, flat tendon which fuses with those that go to the quills.

12. *M. extensor metacarpi ulnaris* (*radialis ?*) (*E. met. ul. r.*, Pl. V, Figs. 19, 20, 22, 24). The origin of this muscle is the most proximal of all that come from the distal end of the humerus. It arises by two heads, one tendinous, the other fleshy, from the anterior surface of the humerus superior to the external condyle and above the upper insertion of the m. propatagialis brevis, the tendinous head being somewhat dorsal. At about 7 mm. from its origin the tendon passes over into a fusiform muscle. At the same point is given off a tendinous sheath which fuses with the tendon of the propatagialis brevis, above the first bifurcation of that tendon. This muscle is smaller and lies dorsal to the one of fleshy origin. About the mid-point of the radius the two muscles unite to form a strong, flat tendon which passes over the end of the radius, across the os radiale, and is inserted on the apex of the os magnum.

13. *M. extensor metacarpi ulnaris* (*E. met. ul.*, Pl. V, Fig. 22). This muscle springs from the external condyle of the humerus close beside the m. extensor digitorum communis. At its origin it is held in place by a delicate ligament. It finds attachment on the posterior surface of the third metacarpal about one third the distance from its proximal end.

14. *M. flexor digitorum sublimis* (*F. dig. s.*, Pl. V, Fig. 24). This is the central superficial muscle of the inner forearm. It arises by a strong, flat tendon from the internal condyle of the humerus. The muscle bundle runs parallel to the ulna, and on the inner side of the flexor carpi ulnaris for about two thirds the length of the ulna, and there separates into two tendons. The posterior tendon passes over the os ulnare, bends under the tendon of the m.

extensor digitorum profundus to the antero-ventral surface of the third metacarpal, runs along the anterior rim of the first phalanx of third digit, and is inserted on the proximal end of the second phalanx about one third its length from the proximal end. The anterior tendon continues to the wrist where it merges into a tendinous band which extends from the ventral edge of the styloid process of the radius to the anterior border of the os ulnare. From this latter point come off two other tendons, the upper and more delicate being inserted at about the mid-point on the ventral border of the third metacarpal. The thin, flat, posterior tendon runs along the ventral surface of the fourth metacarpal and is attached near its distal end. The insertion is quite different from the description of Gadow (*l. c.*).

15. *M. flexor digitorum profundus* (*F. dig. p.*, Pl. V, Fig. 24). This muscle arises fleshily from the proximal half of the ventral surface of the ulna. Proximally it is divided into two almost equal portions by the brachialis inferior which inserts on the ulna between them. The surface of origin gradually diminishes and ceases altogether when the broad expansion of the ulni metacarpalis ventralis is reached. At the wrist the tendon runs under the tendinous band of the m. flexor digitorum sublimis, passes above the ventral projection on the proximal end of the third metacarpal, and is here held in place by a ligament extending from this projection to the distal ventral edge of the radius. It is inserted on the antero-ventral rim of the proximal end of the second phalanx of the third digit.

16. *M. extensor digitorum communis* (*Ex. dig. c.*, Pl. V, Fig. 22). This fusiform muscle arises by a short tendon from the external condyle of the humerus between the tendons of origin of the m. extensor metacarpi ulnaris and m. ectepicondylo radialis. The muscle becomes tendinous at about two thirds the length of the radius. Soon after passing the ulna the tendon bifurcates, sending a delicate slip to the pollex digit, inserting about one third the length of that bone from its proximal end. The long fork is twice crossed by the tendon of the m. extensor indicis longus and is finally inserted on the proximal rim of the first phalanx of the third digit.

17. *M. extensor pollicis longus* (*E. pl. l.*, Pl. V, Figs. 19, 22). Covered by the *m. extensor indicis longus*, the muscle comes from the facing surfaces of ulna and radius, from the proximal third of the

ulna and about the middle third of the radius. At its proximal extremity it is crossed by a ligamentous band passing from ulna to radius. It is also held close to the radius by fascia. The tendon accompanies the m. extensor metacarpi ulnaris (radialis?) to the apex of the os magnum and is there attached below that muscle.

18. *M. extensor indicis longus* (*E. ind. l.*, Pl. V, Figs. 22, 24). This muscle arises by a very short tendon from the internal condyle of the humerus. It passes directly to the ventral surface of the radius, and is attached fleshily to the ulna facing surface of that bone for fully five sixths of its length. The tendon bends under the radius and becomes dorsal. It crosses the tendon of the m. extensor digiterum communis, and finds attachment on the base of the second phalanx of the third digit. It fails to agree with Gadow's diagnosis.

19. *M. interosseus dorsalis* (*Int. d.*, Pl. V, Fig. 21). Both interossei spring from the facing surfaces of the third and fourth metacarpals. In this description the name dorsalis is given to that muscle which clings to the third metacarpal. At the distal end of the interosseous space the muscle becomes tendinous and bends posteriorly, passing along the dorsal surface of the phalanx of the fourth metacarpal, then to the ventral distal end of the second phalanx of third digit to become inserted about four fifths the length of that bone from the proximal end.

20. *M. interosseus palmaris* (*Int. p.*, Pl. V, Fig. 21). This muscle comes from the anterior surface of the fourth metacarpal, and terminates tendinously about one half the length of that bone. The tendon turns dorsally, and is attached to the distal end of the first phalanx of the third digit on its dorsal surface.

21. *M. abductor indicis* (*Ab. in.*, Pl. V, Fig. 20). This muscle springs fleshily from the ventral surface of the proximal two thirds of the third metacarpal, its proximal end being at the base of the ventral projection of that metacarpal. The round, strong tendon is inserted on the proximal anterior rim of the second phalanx of digit three.

22. *M. flexor pollicis* (*Fl. pl.*, Pl. V, Fig. 20). This short muscle comes from the proximal ventral surface of the third metacarpal, lying between the abductor pollicis and the ventral projection of this metacarpal. It terminates on the posterior proximal projection of the pollex digit.

23. *M. abductor pollicis* (*Ab. pl.*, Pl. V, Figs. 20, 24). This rather round muscle arises tendinously from the lower surface of the tendon of the m. extensor metacarpi ulnaris (radialis?) somewhat proximal to its point of insertion. The muscle then twists around the base of the pollex digit to its ventral surface, and terminates tendinously about its mid-point.

24. *M. extensor pollicis brevis* is not present.

25. *M. adductor pollicis* (*Ad. pl.*, Pl. V, Figs. 20, 24). This fairly well developed muscle lies between the posterior surface of the pollex digit and the anterior surface of the third metacarpal. It arises by a strong, fleshy base from the proximal eighth of the third metacarpal, thence it goes obliquely to the pollex digit and is attached by a delicate tendon about one third the length of the digit from its distal end.

26. *M. flexor digiti III* (*F. dig. III*, Pl. V, Figs. 20, 24). This slender muscle has its origin on the posterior proximal third of the fourth metacarpal. At its fleshy base is a broad ligament extending from the anterior rim of the os ulnare to this point. Near the distal end of this metacarpal the muscle becomes tendinous and finds attachment about the mid-point of the first phalanx of fourth digit.

Below are given some muscles found on this bird and not mentioned by Gadow (*l. c.*).

A. (*A.*, Pl. V, Fig. 21.) This is a very delicate muscle extending along the dorsal surface of the third metacarpal, and at its origin is covered by tendons of other muscles, fascia and surrounding membranes. It arises by a delicate tendon from the distal dorsal edge of the radius. The round fusiform carneous portion is covered by the tendons of the extensor digitorum communis and extensor indicis longus. Its distal hair-like tendon fuses with the m. extensor indicis longus at a point opposite the middle of the third metacarpal.

B. (*B.*, Pl. V, Fig. 24.) This slender muscle extends from the distal end of the first phalanx of the third digit to the distal end on the dorsal side of last phalanx of that digit.

C. From the dorsal distal end of the ulna a tendon passes to the quills. It is not shown in the figures.

D. (*D.*, Pl. V, Fig. 21.) This is a flat muscle which has its carneous origin on the proximal dorsal surface of the third metacarpal. It lies between the proximal projection of that bone and the

pollex digit and os magnum. It is inserted tendinously on the proximal ridge of the pollex digit.

E. This is a short, stout muscle arising from the ventral and dorsal end of the coracoid. It passes directly over to the head of the humerus where it is inserted, one point of the insertion extending down to the anterior border of the humeral crest. The long tendon of the biceps passes over this muscle, which does not appear on the plates.

2. *Posterior extremity.*

Here are described only those muscles that insert upon and arise from the femur. The hind limb is so weak in this species and its other muscles so delicate, that it did not seem worth the time to work out its whole musculature. They are described in the order of their occurrence, beginning with the superficial.

1. *M. ilio-tibialis internus or Sartorius* (*Il. tib. int.*, Pl. VI, Figs. 31, 34, 35). This is the most anterior muscle of the thigh, of those extending from pelvis to femur. It comes fleshily from the dorso-lateral border of the ilium and covers the posterior origin of the posterior portion of the latissimus dorsi, and the anterior edge of the ilio-trochanterici. It runs free from the muscles of the pelvis behind it to the femur, gradually diminishing in size and terminating in a flat tendon on the inner surface of the knee joint where it is covered by a lower leg muscle.

2. *M. ilio-trochanterici* (*Il. troch.*, Pl. VI, Figs. 31, 35). This large, somewhat pyramidal-shaped muscle arises fleshily from the region of the acetabulum and that portion of the preacetabular ilium not occupied by the sartorius, the fibers extending even to its ventral border. These converge and insert by a thin tendon on the trochanter where it is covered by the m. ilio-tibialis. It has not the divisions given by Gadow (*l. c.*), but is a compact muscle.

3. *M. ilio-tibialis* (Pl. VI, Figs. 31, 34, 35). This thin, broad muscle is the most superficial one of the thigh. It springs semitendinously from the acetabular and post-acetabular ilium. It consists of an anterior and posterior portion which are readily distinguished. The anterior portion (*Il. tib. ant.*) extends about two thirds the length of the femur, then merges with the underlying muscle. The posterior portion (*Il. tib. post.*) diminishes in width distally and inserts aponeurotically upon the muscles covering the outer surface of the knee joint.

4. *M. caud-ilio-flexorius* (*Caud. il. flx.*, Pl. VI, Figs. 31, 32, 33, 34, 35). Behind the last mentioned muscle this superficial one is found. It is a small band-shaped muscle, coming from the posterior border of the ischium. It is partially covered on its anterior margin by the m. ilio-tibialis and m. ilio-fibularis. The termination is very peculiar. Coming from the under, distal surface of the femur is a short, broad muscle, which fuses with the large muscle mass, the line of fusion being almost at right angles to the fibers of that portion. From its tibial side comes off a short muscle bundle with fibers directed downward and the tendon of which fuses with that of one of the leg muscles. This shows great deviation from Gadow's (*l. c.*) description.

5. *M. ischio-flexorius* (*Isc. flx.*, Pl. VI, Figs. 31, 33, 34, 35). This narrow muscle band comes from the distal border of the ischium at its union with the pubis. It is covered anteriorly by the last mentioned layer. Its thin, flat tendon finds insertion on the anterior borders of the tibial neck.

6. *M. ilio-fibularis* (*Il. fib.*, Pl. VI, Figs. 31, 34, 35). This layer becomes visible after the removal of the m. tibialis anterior and posterior. It springs from the acetabular ilium. It ends in a small, round tendon, which, passing through a tendonous loop at the knee, continues down the leg to become inserted between fibula and tibia at the point where the former becomes free from the latter.

7. *M. femori-tibialis* (*Fm. tib.*, Pl. VI, Figs. 33, 34, 35). This is the largest of the thigh muscles. It is partially covered on the ventral anterior border by the m. ilio-tibialis internus, dorsally by the m. ilio-tibialis anterior. Its origin begins at the trochanter and it is attached fleshily to the femur on both dorsal and ventral surfaces. It finds a tendinous insertion at the knee joint, being attached to the proximal border of the tibia. The separation into parts as given by Gadow (*l. c.*) can not be made out.

8. *M. caud.-ilio-femoralis* (*Caud. il. fm.*, Pl. VI, Fig. 35). This is revealed by the removal of the m. ilio-fibularis and m. caud-ilio-flexorius. Its width where it passes under the m. caud-ilio-flexorius is equal to that of the above muscle. It comes as a small rounded tendon from the ventral lateral border of the pygostyle. Just before reaching the ischium the tendon passes over into the fleshy muscle. This bends around in a semicircular fashion to the proximal

third of the femur, and here finds a fleshy insertion on the linea aspera, occupying its posterior surface. Pars iliaca is absent and pars caudalis does not agree in origin with Gadow's (*l. c.*) description.

9. *M. ischio-femoralis* (*Isc. fm.*, Pl. VI, Fig. 35). This muscle is proximal to the above. It springs from joining surfaces of ischium and ilium and from neighboring surface of ischium down to the origin of the m. pub.-ischo-femoralis. This short, thick, flat muscle there crosses the femur and is inserted by a small, thin tendon at the base of the trochanter.

10. *M. pub-ischio-femoralis* (*Pb. isc. fm.*, Pl. VI, Figs. 33, 35). This is one of the largest muscles of the thigh. It arises from the proximal half of the pubis and ischium along their line of union. It passes somewhat obliquely over to the distal half of the femur and is there inserted fleshily by its anterior border. Its fibers are intimately associated with those of the m. caud-ilio-flexorius. It consists of only one portion, a thick, flat layer.

11. *M. obturator* (*Obt.*, Pl. VI, Fig. 35). This is the deepest lying of the muscles of the outer surface. It springs fleshily from the edges of the foramen obturatum. Thence it passes to the posterior border of femur, and there is attached semitendinously. The muscle varies considerably from that of Gadow's (*l. c.*) of the same name. It agrees in some points with his mm. accessorii m. obturatoris.

12. *M. ilio-femoralis internus* (*Il. fm. int.*, Pl. VI, Fig. 33). This somewhat triangular muscle comes from the ventral surface, near its lateral border, of the preacetabular ilium extending almost to the acetabulum. It passes to the ventral surface of the femur just distal to the head, and is there attached. The muscle is fleshy both at origin and insertion.

13. *X.* (Pl. VI., Fig. 33). This is a long slender muscle beginning distal to the insertion of the m. ilio-femoralis internus, and is attached fleshily to the ventral surface of the femur for its remaining length. It terminates distally in a thin, flat tendon which is inserted on the dorso-ventral border of the proximal end of the tibia. Gadow (*l. c.*) did not describe such a muscle.

The following muscles were not found: ***m. ilio-femoralis externus***, *m. ambiens*, *mm. accesorii m. obturatoris*.

VII. Comparisons.

Certain characters of the better known genera of the Caprimulgidæ are compared in the following table:

	Carotids.	Cæca.	Oil Gland.	Biceps Slip.	Gall Bladder.	Glutæus.	Thigh Muscles.	Sternum.	Syrinx.	Last Toe with Four Phalanges.	Middle Toe Serrated.	Powder Downs.
Caprimulgus.	2	x	x	x	x	Over biceps.	Axy	One notch.	Traches-bronchial.	x	x	—
Nyctidromus.	2	x	x	x	x	"	Axy	"	"	x	x	—
Chordeiles.	2	x	x	x	—	"	Axy	"	"	x	x	—
Antrostomus.	2	x	x	x	x	"	Axy	"	"	x	x	—
Phalænoptilus.	2	x	x	—	x	"	(A)y	"	"	x	x	—

The sign "x" denotes occurrence, and "—" absence of a character. The formulæ for the thigh muscles are those given by Garrod (1874), slightly modified by Gadow (1891), and denote the presence of the following muscles:

Pars caudalis m. caud.-il. femoris .... = A
Pars iliaca m. caud-il. femoris .... = B
M. caud-il. flex. inserting only on the tibia .... = X
M. caud-il. flex. with the "accessorius" inserting on the femur .... = Y

All the points of comparison of the first four genera in the above table were taken from Beddard (1898). It will be noticed that the amount of difference in these forms is slight. The only characters which differ are the gall bladder, absent in *Chordeiles*, biceps slip, absent in *Phalænoptilus*, and the difference in the last genus of the muscle formula for the thigh.

So far as the tabulated characters are concerned, *Phalænoptilus* appears less closely related to *Chordeiles* than to the other genera. In two of its muscle characters it differs from all the other genera.

VIII. Aberrant Characters.

In closing it will be well to call attention to the striking variations from the muscles of the birds studied and described by Gadow (*l. c.*).

The following wing muscles were not found: Biceps slip, m. extensor policis brevis, m. entepicondylo-ulnaris and m. deltoideus minor. Some not mentioned by him were present in the

bird, and in the descriptions and drawings are denoted by the letters *A*, *B*, *C*, *D*, and *E*. The complex arrangement of the m. propatagialis brevis should also be mentioned.

Of the thigh muscles these were missing: m. ilio-femoralis externus, m. ambiens, and mm. accessorii m. obturatoris. A muscle herein denoted by the letter *X* was not given by Gadow. Pars caudalis m. caud-ilio-femoralis differs from Gadow's description and this difference is indicated in the table by placing the letter representing it in parenthesis. M. caud-ilio-flexorius showed considerable variation.

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ZOÖLOGICAL LABORATORY,
UNIVERSITY OF TEXAS, 1905.

DESCRIPTION OF THE PLATES.

The following abbreviations have been employed:

Ab. in., Musculus abductor indicis.
Ab. pl., M. abductor pollicis.
Ad. pl., M. adductor pollicis.
A., Anus.
Bas. h., Basihyal.
Bas. b., Basibranchial.
Bi., Biceps brachii, pars propatagialis.
Bi. T., Tendon of biceps brachii.
Bi. inf., Musculus brachialis inferior.
Br. n., Brachial nerve.
Bro., Bronchus.
C., Coracoid.
Cæ., Cæca.
Caud. il. flx., Musculus caud.-ilio-flexorius.
Caud. il. fm., M. caud.-ilio femoralis.
Cb., Cerebellum.
Cer., Cerebrum.
Cer. b., Cerato-brachial.
Cl., Clavicle.
Clo., Cloaca.
Cor. br. p., Musculus coraco-brachialis posterior.
Del. a., M. deltoideus major anterior.
Del. p., M. deltoideus major posterior.
Duo., Duodenum.
Ect. r., Musculus ectepicondylo-radialis.
Ect. u., M. ectepicondylo-ulnaris.
E. dig. c., M. extensor digitorum communis.
E. dig. c. t., Tendon of m. extensor digitorum communis.
E. ind. l., Musculus extensor indicis longus.
E. ind. l. t., Tendon of M. extensor indicis longus.
E. met. ul., Musculus extensor metacarpi ulnaris.
E. met. ul. r., M. extensor metacarpi ulnaris (radialis?).
E. met. ul. r. t., Tendon of m. extensor metacarpi ulnaris (radialis?).
Ent. g., Os entglossum.
E. pl. l., Musculus extensor pollicis longus.
Ep. b., Epi-branchial.
F. carp. ul., Musculus flexor carpi ulnaris.
F. dig. p., M. flexor digitorum profundus.
F. dig. s., M. flexor digitorum sublimis.
F. dig. III., M. digiti III.
Fl. pl., M. flexor pollicis.
Flo., Flocculus.
Fm. tib., M. femori-tibialis.
G. bl., Gall bladder.
Giz., Gizzard.
Ht., Heart.

Hu., Humerus.
Il. fib., Musculus ilio-fibularis.
Il. fm. int., M. ilio-femoralis internus.
Il. tib. ant., M. ilio-tibialis anterior.
Il. tib. post., M. ilio-tibialis posterior.
Il. tib. int., M. ilio-tibialis internus.
Il. troch., M. ilio-trochanterici.
Inf., Infundibulum.
Int., Intestine.
Int. d., Musculus interosseus dorsalis.
Int. p., M. interosseus palmaris.
Isc. flx., M. ischio-flexorius.
Isc. fm., M. ischio-femoralis.
K., Kidney.
Lar., Larynx.
Lat. d. a., Musculus latissimus dorsi anterior.
Lat. d. p., M. latissimus dorsi posterior.
Liv., Liver.
Liv. d., Liver duct.
L. ovi., Left ovary.
Lu., Lungs.
Med., Medulla oblongata.
Nos., Nostril.
Obt., Musculus obturator.
Œs., Œsophagus.
Olf. n., Olfactory nerve.
Op. l., Optic lobes.
Ov., Ovary.
Pars. hu. cub., Musculus triceps pars humero-cubitalis.
Pars. sc. cub., M. triceps pars scapuli-cubitalis.
Pan., Pancreas.
Pan. d., Pancreatic ducts.
Pb., Pubis.
P. pat. b., Musculus propatagialis brevis.
P. pat. l., M. propatagialis longus.
Pb. isc. fm., M. pub.-ischio-femoralis.
Pect., M. pectoralis, pars thoracica.
Pha., Pharynx.
Pron. s., Musculus pronator sublimis.
Pro., M, propatagialis, pars propatagialis musculi deltoidei.
Prov., proventriculus.
R., Os radiale.
Ra., Radius.
Rh. s., Musculus rhomboideus superficialis.
Rh. p., M. rhomboideus profundus.
R. ovi., Right oviduct.
Sc., Scapula.
Sc. hum. p., Musculus scapuli-humeralis posterior.
Ser. p., M. serratus profundus.
Ser. s. a., M. serratus superficialis anterior.
Ser. s. p., M. serratus superficialis posterior.
Spl., Spleen.
Sp., Spinal cord.
S. sc., Musculus subscapularis.
St., Sternum.
St. co., Musculus sterno-coracoideus.
St. tr., M. sterno-trachealis.
Sub. co., Musculus subcoracoideus.
Sup. cor., M. supracoracoideus.
T., Tongue.
Tr. lat., Musculus Tracheo-lateralis.
Tra., Trachea.
Tym. in., Membrana tympaniformis interna.
Tym. ex., Membrana tympaniformis externa.
U., Os ulnare.
Ul., Ulna.
Ul. met. d., Musculus ulni metacarpalis dorsalis.
Ul. met. v., M. ulni metacarpalis ventralis.
Urh., Urohyal.
Ur., Ureter.

EXPLANATION OF PLATES.

All the figures are from enlarged freehand sketches, and are mostly drawn to the same scale; they have been reduced almost one half in the reproduction.

PLATE IV.

Fig. 1. Tongue bone.

Fig. 2. Dorsal view of brain with outline of head and nostrils.

Fig. 3. Brain viewed from the right side.

Fig. 4. Lateral view of pecten of the eye.

Fig. 5. Pecten seen from its free apex.

Fig. 6. Dorsal view of duodenal loop and pancreas.

Fig. 7. Ventral view of syrinx.

Fig. 8. Dorsal view of syrinx.

Fig. 9. Viscera seen from the right side.

Fig. 10. Ventral view of head, trachea and viscera.

Fig. 11. Female urogenital organs, ventral view.

Fig. 12. Ventral view of posterior portion of alimentary tract.

Fig. 13. Dorsal view of oil gland.

Fig. 14. Lateral view of the same.

Fig. 15. Lateral view of viscera showing intestinal loops. Dotted lines represent the portion of the intestine covered by superficial folds.

PLATE V.

Fig. 16. Muscles of upper wing.

Fig. 16*a*. Dorsal view of spinal cord and brachial nerve plexus.

Fig. 17. Superficial muscles of back and upper wing.

Fig. 18. Dorsal superficial muscles of hand.

Fig. 19. Deeper muscles of forearm.

Fig. 20. Muscles of ventral surface of hand.

Fig. 21. Muscles of dorsal surface of hand.

Fig. 22. Superficial muscles of back and outer arm.

Fig. 23. M. propatagialis brevis removed to show more clearly its complex arrangement.

Fig. 24. Superficial muscles of breast and inner arm.

PLATE VI.

Fig. 25. Deeper chest muscles.

Fig. 26. Muscles of shoulder and chest.

Figs. 27, 28 and 29. Upper arm muscles.

Fig. 30. Origin of m. coraco-brachialis posterior.

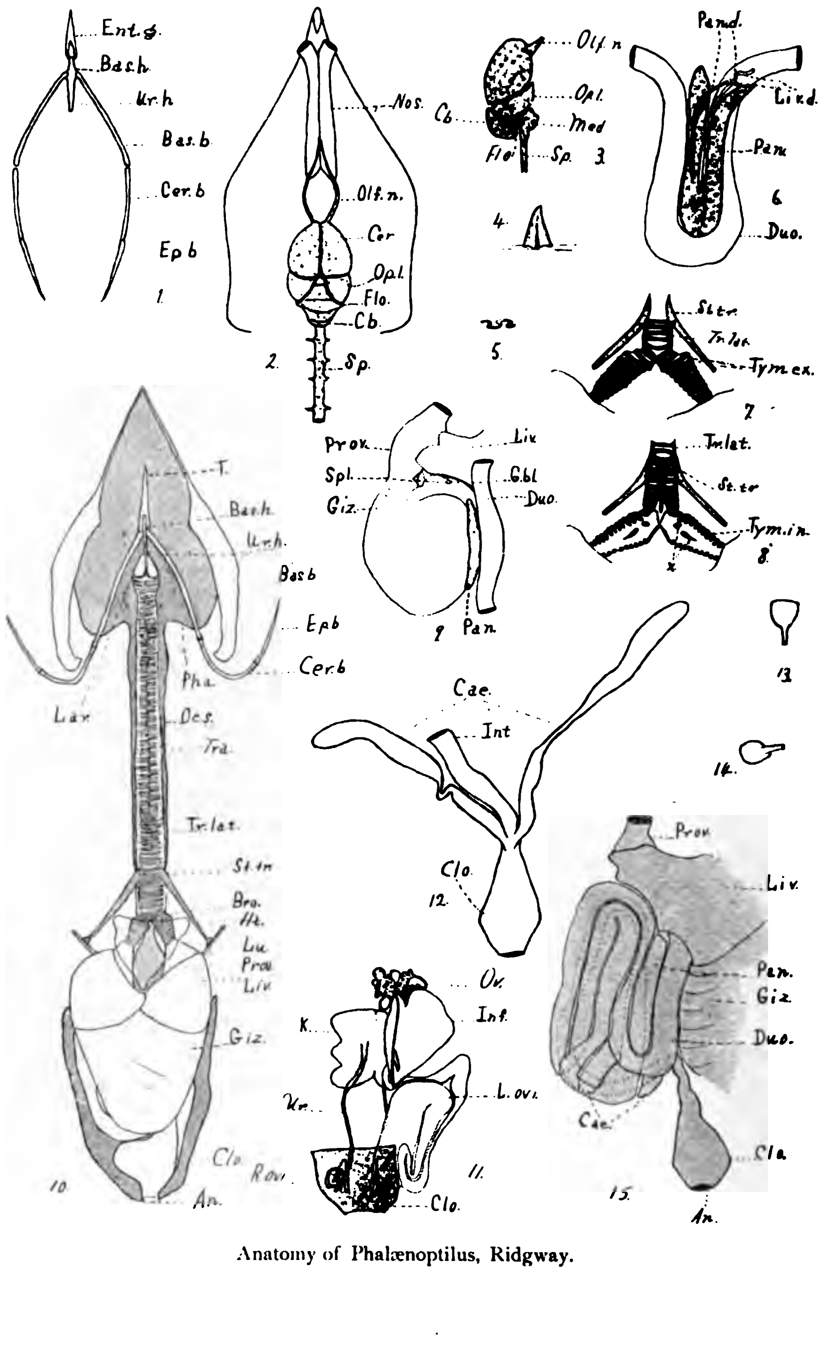
Fig. 31. Superficial muscles of thigh.

Fig. 32. M. caud.-ilio flexorius removed to show complex arrangement.

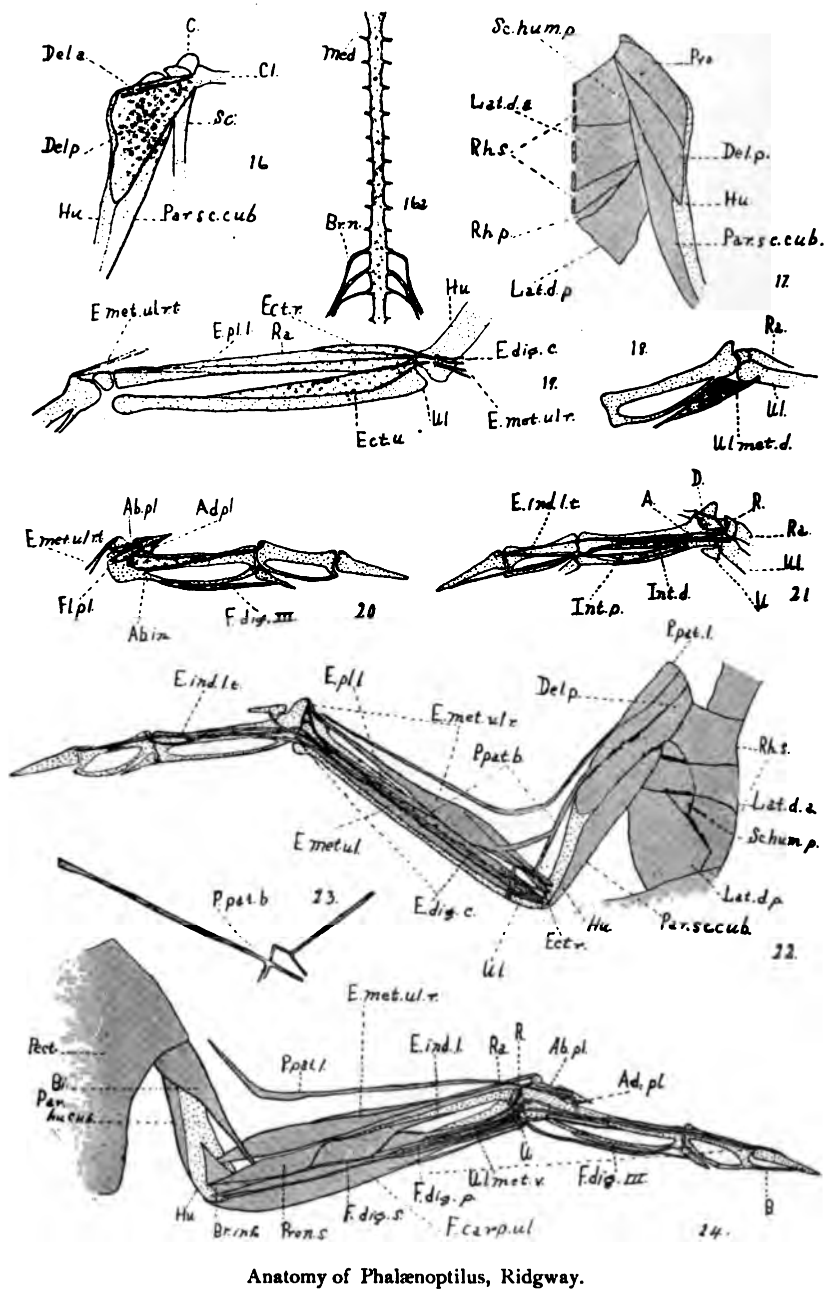
Fig. 33. Muscles of thigh viewed from median surface.

Fig. 34. Deeper thigh muscles.

Fig. 35. Deepest muscles of thigh.



Anatomy of Phalænoptilus, Ridgway.



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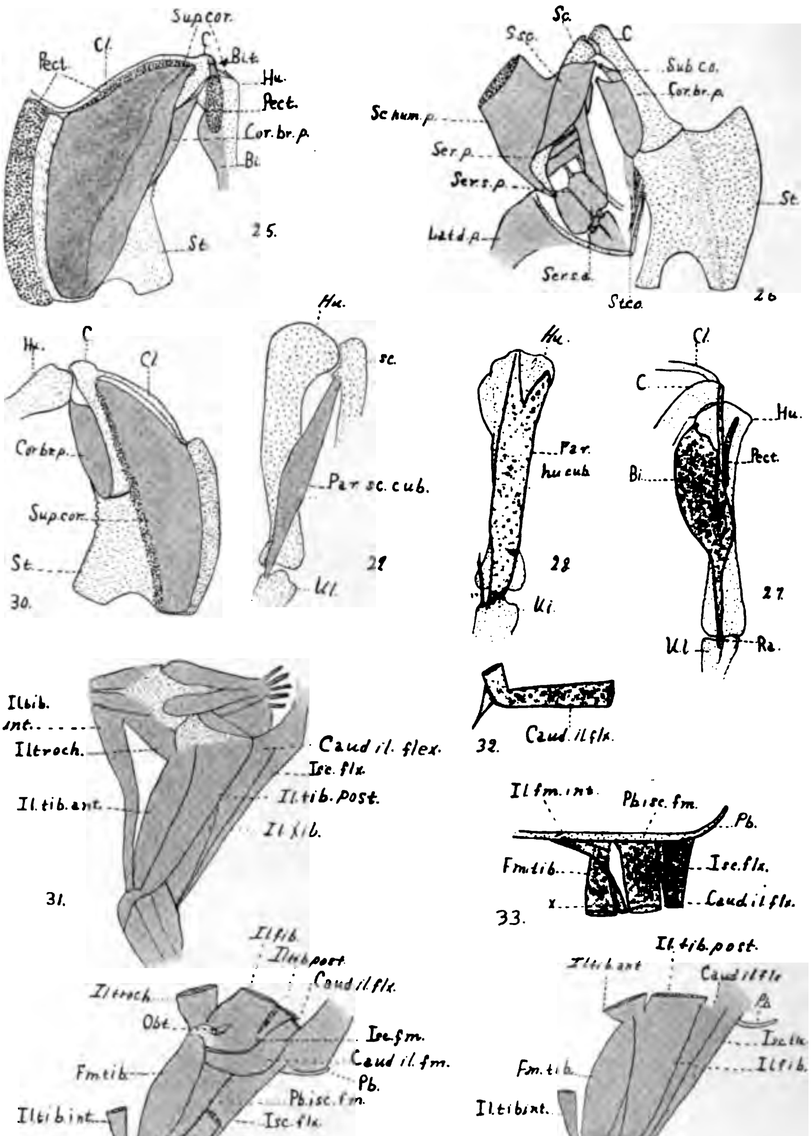

Anatomy of Phalænoptilus, Ridgway.

Stated Meeting, April 28, 1905.

President SMITH in the Chair.

Letters accepting membership were read from Prof. Joseph S. Ames, President David Starr Jordan, Prof. G. L. Kittridge, Dr. Robert G. LeConte, Mr. George T. Moore, President Francis P. Venable and Mr. J. Edward Whitfield.

Dr. J. W. Harshberger read a paper on "Evolution and Distribution of North American Plants."

Stated Meeting, May 5, 1905.

President SMITH in the Chair.

Dr. Robert G. LeConte and Mr. J. Edward Whitfield, newly elected members, were presented to the Chair and took their seats in the Society.

Letters accepting membership were read from Mr. R. A. F. Penrose, Jr., Prof. W. G. Farlow and Prof. Eliakim Hastings Moore.

Mr. Sydney George Fisher read a paper on "The Military Strategy of the American Revolution."

Mr. Joseph Willcox exhibited a fossil specimen of bone from the tail of the Glyptodon found in Florida.

Stated Meeting, May 19, 1905.

President SMITH in the Chair.

Mr. R. A. F. Penrose, Jr., a newly elected member, was presented to the chair and took his seat in the Society.

Letters accepting membership were read from Prof. T. C.

Chamberlin, Prof. Yves Delage, Prof. W. M. Flinders-Petrie, Sir W. T. Thiselton-Dyer, and Prof. Otto Nordenskjöld.

Dr. Henry Skinner read a paper on "Insects in Relation to Disease."

Dr. Edgar F. Smith read a paper entitled "Observations on Columbium."

Stated Meeting, October 6, 1905.

President SMITH in the Chair.

Mr. Henry Carey Baird presented his resignation of membership which was accepted.

The decease was announced of the following members:

Hon. John Hay, at Newbury, N. H., on July 1, 1905, æt. 66.

Prof. William C. Day, at Swarthmore, Pa., on August 4, 1905, æt. 48.

Prof. Franz Reuleaux, at Berlin, on August 20, 1905, æt. 76.

Prof. Dr. Jules Oppert, at Paris, on August 21, 1905, æt. 80.

Gen. Isaac J. Wistar, at Claymont, Del., on September 18, 1905, æt. 78.

Mr. Ellis Yarnall, at Philadelphia, on September 19, 1905, æt. 87.

The following papers were read:

"The Problems of Human Anatomy," by Dr. George A. Piersol.

"New Species of Drosera from the Gulf States," by Dr. John Macfarlane.

"A Study of the Anatomy of Phalænoptilus, Ridgway," by Margaret E. Marshall, communicated by Prof. Thos. H. Montgomery. (See page 213.)

Stated Meeting, October 20, 1905.

President SMITH in the Chair.

The following papers were read:

"Eclipse Problems," by Prof. C. L. Doolittle.

"Some of the Vertebrates of the Florida Keys," by Henry W. Fowler.

Mr. Samuel Dickson was elected a Councillor to fill the unexpired term of Gen. Isaac J. Wistar, deceased, and Prof. Henry F. Osborn was elected a Councillor to fill the unexpired term of Mr. Henry Carey Baird, resigned.

Stated Meeting, November 3, 1905.

President SMITH in the Chair.

A letter was presented from Mr. Bailey Willis, accepting membership.

Dr. Franz Boas read a paper on "Party Allegiance from the Anthropological Point of View."

Stated Meeting, November 17, 1905.

President SMITH in the Chair.

The decease was announced of Dr. George R. Morehouse, at Philadelphia, on November 12, 1905, æt. 76.

Dr. Charles Conrad Abbott read a paper on "The Antiquit, of Man in the Delaware Valley."

Stated Meeting, December 1, 1905.

President SMITH in the Chair.

Prof. John M. Macfarlane read a paper on the "Occurrence Distribution and Hybridization of the American Pitcher Plants, or Sarracenias."

Stated Meeting, December 15, 1905.

President SMITH in the Chair.

A letter was read from the Committee on Organization of the 6th Congrès Internationale d' Anthropologie Criminelle, announcing that the Congress would convene at Turin on April 28, 1906, and inviting the Society to be represented thereat.

The President delivered his Annual Address which included "The Story of the Isolation of the Metal Calcium."

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1895	BRUBAKER, ALBERT P., M.D.	105 N. 34th St., Philadelphia.
1865	BRUSH, Prof. GEORGE J.	Yale Univ., New Haven, Conn.
1898	BRYANT, HENRY GRIER, F.R.G.S.	805 Land Title Building, Philadelphia.
1895	BRYCE, RIGHT HON. JAMES	54 Portland Place, London, W., England.
1895	BUDGE, E. A. WALLLIS, Litt.D.	British Museum, London, Eng.
1881	BUTLER, HON. WILLIAM	West Chester, Pa.
1899	CADWALADER, JOHN	1519 Locust St., Philadelphia.
1903	CAMPBELL, WM. WALLACE, LL.D.	Lick Observatory, Mt. Hamilton, California.
1885	CANNIZZARO, TOMASO	Santa Maria fuori cinta, Casa Roffa, Messina, Sicily.
1873	CAPELLINI, Prof. GIOVANNI	Portovenere près Spezia, Italy.
1875	CARLL, Prof. JOHN FRANKLIN	Pleasantville, Venango Co., Pa.
1902	CARNEGIE, ANDREW, LL.D.	2 E. 91st St., New York, N. Y.
1880	CARSON, HAMPTON L., LL.D.	1033 Spruce St., Philadelphia.
1872	CASSATT, ALEXANDER JOHNSON	Haverford, Delaware Co., Pa.
1887	CASTNER, SAMUEL, JR.	3729 Chestnut St., Phila.
1888	CATTELL, Prof. J. McKEEN	Garrison-on-Hudson, N. Y.
1905	CHAMBERLIN, THOMAS CHROWDER, LL.D.	Univ. of Chicago, Chicago, Ill.
1880	CHANCE, HENRY MARTYN, M.D.	819 Drexel Building, Phila.
1875	CHANDLER, Prof. C. F.	Columbia Univ., N. Y. City.
1875	CHAPMAN, HENRY C., M.D.	2047 Walnut St., Phila.
1886	DECHARENCEY, COMTE HYACINTH	25 Rue Barbet de Jouy, Paris, France.
1904	CHEYNEY, Prof. EDWARD POTTS	259 S. 44th St., Philadelphia.
1904	CHITTENDEN, Prof. RUSSEL H., Ph.D.	83 Trumbull St., New Haven, Conn.
1889	CLARK, CLARENCE H.	42d and Locust Sts., Phila.
1902	CLARK, Prof. WILLIAM BULLOCK	Johns Hopkins University, Baltimore, Maryland.
1904	CLARK, FRANK WIGGLESWORTH, Sc.D.	U. S. Geological Survey, Washington, D. C.
1883	CLAYPOLE, Prof. E. W.	Pasadena, Cal.
1895	CLEEMANN, RICHARD A., M.D.	2135 Spruce St., Philadelphia.
1897	CLEVELAND, HON. GROVER	Westland, Princeton, N. J.
1899	COLES, EDWARD	2010 DeLancey Place, Phila.
1902	COLLITZ, Prof. HERMANN, Ph.D.	Bryn Mawr, Pa.

Elected.	*Name.*	*Present Address.*
1897	CONKLIN, Prof. EDWIN GRANT	University of Penn., Phila.
1898	CONVERSE, JOHN H.	500 N. Broad St., Phila.
1895	COOK, JOEL	849 N. Broad St., Phila.
1886	CORA, Prof. GUIDO	2 Via Goito, Rome Italy.
1892	CRAMP, CHARLES H.	Aldine Hotel, Philadelphia.
1877	CRANE, Prof. THOMAS FREDERICK	Cornell Univ., Ithaca, N. Y.
1886	CROOKES, SIR WILLIAM	7 Kensington Park Gardens, London, W., England.
1898	CROWELL, Prof. EDWARD P.	21 Amity St., Amherst, Mass.
1897	CULIN, STEWART	Brooklyn Institute of Arts and Sciences, Brooklyn, N. Y.
1904	DA COSTA, JOHN CHALMERS, M.D.	2045 Walnut St., Phila.
1897	DALL, Prof. WILLIAM H.	U. S. National Museum, Washington, D. C.
1899	DANA, CHARLES E.	2013 DeLancey Place, Phila.
1896	DANA, Prof. EDWARD S.	Yale Univ., New Haven, Conn.
1902	DARBOUX, JEAN-GASTON	36 Rue Gay-Lussac, Paris, France.
1898	DARWIN, Sir GEORGE HOWARD, K.C.B.	Newnham Grange, Cambridge, England.
1876	DAVENPORT, SIR SAMUEL	Beaumont, Adelaide, S. Australia.
1866	DAVIDSON, Prof. GEORGE	2221 Washington St., San Francisco, Cal.
1899	DAVIS, Prof. WILLIAM MORRIS	Cambridge, Mass.
1880	DAWKINS, Prof. WILLIAM BOYD	Woodhurst, Fallowfield, Manchester, England.
1899	DAY, FRANK MILES	Allen's Lane, Mount Airy, Philadelphia.
1905	DELAGE, Prof. YVES	Université de Paris, Station Zoologique de Roscoff, Paris, France.
1904	DELITZSCH, Prof. FRIEDRICH, Ph.D.	University of Berlin, Berlin, Germany.
1892	DERCUM, FRANCIS X., M.D.	1719 Walnut St., Phila.
1899	DEWAR, Prof. JAMES, LL.D.	The Royal Institution, London, England.
1884	DICKSON, SAMUEL	901 Clinton St., Philadelphia.
1892	DIXON, SAMUEL G., M.D.	Black Rock Farm, Ardmore, Pa.
1903	DOHRN, Dr. ANTON	Marine Zoological Station, Naples, Italy.
1886	DOLLEY, CHARLES S., M.D.	3707 Woodland Ave., Phila.
1886	DONNER, Prof. OTTO	Helsingfors, Finland.
1881	DOOLITTLE, Prof. C. L.	Upper Darby, Delaware Co., Pa.

Elected.	*Name.*	*Present Address.*
1903	DOOLITTLE ERIC	University of Pennsylvania, Philadelphia.
1899	DOUGHERTY, THOMAS HARVEY	School House Lane, Germantown, Philadelphia.
1877	DOUGLASS, JAMES, LL.D	Spuytenduyvil, New York, N. Y.
1880	DRAPER, DANIEL, Ph.D	Meteorological Observatory, Central Park, New York, N. Y.
1880	DU BOIS, PATTERSON	401 S. 40th St., Philadelphia.
1879	DUDLEY, CHARLES BENJ., Ph.D	Box 156, Altoona, Blair Co., Pa.
1886	DUNCAN, LOUIS, Ph.D., U.S.N	56 Pine St., New York, N. Y.
1867	DUNNING, GEORGE F	500 Madison Ave., New York, N. Y.
1873	DUPONT, EDOUARD	Royal Museum, Bruxelles, Belgique.
1894	DUPONT, Col. HENRY A	Winterthur, Del.
1871	DUTTON, Maj. CLARENCE E., U.S.A.	Englewood, N. J.
1880	ECKFELDT, JACOB B	U. S. Mint, Philadelphia.
1877	EDDY, Prof. H. TURNER	University of Minnesota, Minneapolis, Minn.
1896	EDISON, THOMAS ALVA, Ph.D	Orange, N. J.
1895	EDMUNDS, HON. GEORGE F	Aiken, S. C.
1871	ELIOT, Pres't CHARLES W	17 Quincy St., Cambridge, Mass.
1895	ELLIOTT, Prof. A. MARSHALL	Johns Hopkins University, Baltimore, Md.
1897	ELY, THEODORE N., C.E	115 Broad St. Station, Phila.
1897	EMERSON, Prof. BENJ. KENDALL	Amherst, Mass.
1898	EMMET, W. L. R	48 Washington Ave., Schenectady, N. Y.
1883	EMMONS, Prof. S. F	1721 H St., Washington, D. C.
1881	EVANS, SIR JOHN, K.C.B	Nash Mills, Hemel Hempstead, England.
1895	EWELL, MARSHALL D., M.D., LL.D.	59 Clark St., Chicago, Ill.
1905	FARLOW, Prof. WILLIAM GILSON	Cambridge, Mass.
1895	FENNEL, C. A. M., Litt.D	139 Chesterton Road, Cambridge, England.
1890	FIELD, ROBERT PATTERSON	218 S. 42d St., Philadelphia.
1897	FINE, Prof. HENRY B	Princeton, N. J.
1897	FISHER, SYDNEY GEORGE, LL.D	328 Chestnut St., Phila.
1901	FLEXNER, SIMON, M.D	Rockefeller Institute, 50th and Lexington Ave., New York.
1880	FLINT, AUSTIN, M.D	60 E. 34th St., New York, N. Y.

Elected.	Name.	Present Address.
1891	FORBES, Prof. GEORGE, F.R.S	34 Great George St., S. W., London.
1902	FOSTER, SIR MICHAEL, K.C.B., F.R.S., D.C.L	Nine Wells, Great Shelford, Cambridge, Eng.
1880	FRALEY, JOSEPH C	1833 Pine St., Philadelphia.
1904	FRANCKE, Prof. KUNO, Ph.D	Harvard University, Cambridge, Mass.
1872	FRAZER, PERSIFOR, Dr. ès-Sc. Nat	928 Spruce St., Philadelphia.
1889	FRIEBIS, GEORGE, M D	1906 Chestnut St., Phila.
1890	FULLERTON, Rev GEORGE S	Columbia University, New York, N. Y
1873	FULTON, JOHN	136 Park Pl., Johnstown, Pa.
1880	FURNESS, HORACE HOWARD, LL.D	Wallingford, Del. Co., Pa.
1897	FURNESS, HORACE HOWARD, JR	2034 DeLancey Place, Phila.
1897	FURNESS, WILLIAM H., 3d, M.D	The Warwick, 1906 Sansom St., Philadelphia.
1901	GARNETT, RICHARD, C.B., LLD	27 Tanza Road, Hampstead, London, England.
1886	GATES, MERRILL E., LL.D	1315 New Hampshire Ave., Washington, D. C.
1884	GATSCHET, ALBERT S., Ph.D	2020 Fifteenth St., N. W., Washington, D. C.
1880	GEIKIE, SIR ARCHIBALD	28 Jermyn St., London, S. W., England.
1876	GEIKIE, Prof. JAMES	83 Colinton Rd. Edinburgh, Scotland.
1886	GENTH, Prof. F. A., JR	222 Walnut St., Phila.
1854	GIBBS, Prof. OLIVER WOLCOTT	158 Gibbs Ave., Newport, R. I.
1901	GIGLIOLI, Prof. HENRY H	19 Via Romana,Florence,Italy.
1902	GILBERT, GROVE KARL, LL.D	U. S. Geological Survey, Washington, D. C.
1903	GILDERSLEEVE, Prof. BASIL L.,LL.D	1002 Belvidere Terrace, Baltimore, Md.
1867	GILL, THEODORE N., M.D., Ph.D	Smithsonian Institution, Washington, D. C.
1876	GILMAN, DANIEL C., LL.D	614 Park Ave., Baltimore, Md.
1895	GLAZEBROOK, RICHARD T., F.R.S	Bushey House, Teddington, Middlesex, Eng.
1893	GOODALE, Prof. GEORGE LINCOLN	10 Craigie St., Cambridge, Mass.
1896	GOODSPEED, Prof. ARTHUR W	Univ. of Pennsylvania, Phila.
1892	GOODWIN, HAROLD	133 S. 12th St., Philadelphia.
1895	GOODWIN, Prof. W. W	Cambridge, Mass.
1900	GRAY, GEORGE, Hon	Wilmington, Del.
1904	GREELY, GEN. ADOLPHUS W., U.S.A	1914 G St., Washington, D. C.

Elected.	Name.	Present Address.
1893	Green, Samuel A., M.D	Historical Soc., Boston, Mass.
1879	Greene, William H., M.D	N. E. Cor. Arch and 16th Sts., Philadelphia.
1899	Greenman, Milton J., M.D	Wistar Institute, 36th St. and Darby Road, Philadelphia.
1888	di Gregorio, Marquis Antonio	Al Molo, Palermo, Sicily.
1891	Gregory, Prof. Caspar René	Naunhoferstrasse 5 Marienhöhe, Leipzig-Stötteritz, Germany.
1886	de Gubernatis, Prof. Angelo	Florence, Italy.
1903	Gummere, Prof. Francis Barton, Ph.D	Haverford College, Haverford, Pa.
1902	Hadley, Pres't Arthur T	Yale University, New Haven, Conn.
1885	Haeckel, Prof. Dr. Ernst	University, Jena, Germany.
1903	Hague, Arnold, D.Sc	1724 I St., Washington, D. C.
1870	Hale, Rev. Edward Everett	39 Highland St., Roxbury, Mass.
1902	Hale, Prof. George E	Yerkes Observatory, Williams Bay, Wis.
1878	Hall, Prof. Asaph	South Norfolk, Conn.
1875	Hall, Charles Edward	Instituto Geologico de Mexico, Santa Maria, Mexico, Mex.
1898	Hall, Charles M	136 Buffalo Ave., Niagara Falls, N. Y.
1885	Hall, Prof. Lyman B	Haverford Coll., Haverford, Pa.
1891	Hamy, Dr. Ernst T	40 Rue Lübeck, Ave. du Trocadero, Paris, France.
1887	Harris, Joseph S	144 School Lane, Germantown, Philadelphia.
1895	Harrison, Provost Charles C	400 Chestnut St., Phila.
1877	Hart, Prof. James Morgan	1 Reservoir Ave., Ithaca, N. Y.
1878	Haupt, Prof. Lewis M	107 N. 35th St., Philadelphia.
1902	Haupt, Prof. Paul	2511 Madison Ave., Baltimore.
1886	Hays, I. Minis, M.D	266 S. 21st St., Philadelphia.
1883	Heilprin, Prof. Angelo	1801 Arch St., Philadelphia.
1893	Hewett, Prof. Waterman T	31 East Ave., Ithaca, N. Y.
1895	Heyse, Paul, Ph.D	Munich, Bavaria.
1903	Hill, George William, LL.D	West Nyack, N. Y.
1897	Hiller, H. M., M.D	Kohoka, Mo.
1886	Hilprecht, Prof. Hermann V	Free Museum of Art, Univ. of Penn., Phila.
1874	Himes, Prof. Charles Francis	Dickinson Coll., Carlisle, Pa.
1899	Hirst, Barton Cooke, M.D	1821 Spruce St., Philadelphia.

Elected.	Name.	Present Address.
1870	HITCHCOCK, Prof. CHAS. HENRY	Dartmouth College. Hanover, N. H.
1897	HOLDEN, Prof. EDWARD S.	U. S. Military Academy, West Point, N. Y.
1886	HOLLAND, JAMES W., M.D.	2006 Chestnut St., Phila.
1899	HOLMES, Prof. WILLIAM H.	Bureau of Ethnology, Smithsonian Institution, Washington, D. C.
1869	HOOKER, SIR JOSEPH D., LL.D.	The Camp, Sunningdale, Eng.
1893	HOPPIN, Prof. J. M.	New Haven, Conn.
1886	HORNER, INMAN	1811 Walnut St., Phila.
1872	HOUGH, Prof. GEORGE W.	Northwestern University, Evanston, Ill.
1872	HOUSTON, Prof. EDWIN J.	1809 Spring Garden St., Phila.
1897	HOWE, Prof. HENRY M.	27 W. 73d St., New York City.
1903	HOWELL, Prof. WILLIAM HENRY	232 W. Lanvale St., Baltimore.
1895	HUGGINS, SIR WILLIAM, K.C.B.	90 Upper Tulse Hill, S. W., London, England.
1877	HUMPHREY, H. C.	?
1895	HUNTER, RICHARD S.	1413 Locust St., Phila.
1898	HUTCHINSON, EMLEN	Aldine Hotel, Philadelphia.
1875	INGHAM, WM. ARMSTRONG	320 Walnut St., Phila.
1893	D'INVILLIERS, EDWARD VINCENT	506 Walnut St., Phila.
1884	JAMES, Pres't EDMUND J.	Urbana, Ill.
1897	JASTROW, Prof. MORRIS, JR.	248 S. 23d St., Philadelphia.
1898	JAYNE, HENRY LABARRE	1826 Chestnut St., Phila.
1885	JAYNE, HORACE, M.D.	318 S. 19th St., Philadelphia.
1882	JEFFERIS, WILLIAM W.	474 Central Park West, New York City.
1905	JORDAN, Pres't DAVID STARR	Stanford Univ., Cal.
1884	JORDAN, FRANCIS, JR.	111 N. Front St., Phila.
1883	KANE, ELISHA KENT	Kushequa, Pa.
1897	KARPINSKY, Prof. ALEX. PETROVITCH	Geological Survey, St. Petersburg, Russia.
1889	KEANE, Right Rev. JOHN J.	Dubuque, Iowa.
1899	KEASBEY, Prof. LINDLEY M.	Univ. of Texas, Austin, Texas.
1897	KEEN, GREGORY B.	3237 Chestnut St., Phila.
1884	KEEN, WILLIAM W., M.D., LL.D. (Edin.)	1729 Chestnut St., Phila.
1898	KEISER, Prof. EDWARD H.	Washington University, St. Louis, Mo.
1900	KELLER, Prof. HARRY F.	Central High School, Phila.
1873	KELVIN, RIGHT HON. LORD	The Library, The University, Glasgow, Scotland.
1896	KENNELLY, A. E., D.Sc.	Harvard University, Cambridge, Mass.

Elected.	*Name.*	*Present Address.*
1905	KITTREDGE, GEORGE LYMAN, LL.D.	8 Hilliard St., Cambridge, Mass.
1898	KNIGHT, Prof. WILLIAM A.	Holmleigh, Malvern, Eng.
1874	KÖNIG, Prof. GEORGE A.	School of Mines, Houghton, Mich.
1899	KRAEMER, Prof. HENRY	145 N. 10th St., Philadelphia.
1889	KRAUSS, FRIEDRICH S., Ph.D.	VII[2] Neustiftgasse 12, Vienna, Austria.
1872	LAMBERT, Prof. GUILLAUME	42 Boulevard Bischoffsheim, Brussels, Belgium.
1904	LAMBERT, Prof. PRESTON A.	Lehigh University, Bethlehem, Pa.
1899	LAMBERTON, Prof. WILLIAM A.	University of Penna., Phila.
1898	DE LANCEY, EDWARD F.	20 E. 28th St., New York.
1897	LANCIANI, Prof. RODOLFO	2 Via Goito, Rome, Italy.
1878	LANDRETH, BURNET	Bristol, Pa.
1875	LANGLEY, SAMUEL P., LL.D.	Smithsonian Institution, Washington, D. C.
1903	LANKESTER, EDWIN RAY, LL.D., F.R.S.	British Museum, Cromwell Rd., London, S. W., Eng.
1873	LA ROCHE, C. PERCY, M.D.	1518 Pine St., Philadelphia.
1867	LEA, HENRY CHARLES, LL.D.	2000 Walnut St., Phila.
1899	LEARNED, Prof. MARION D.	University of Penna., Phila.
1905	LECONTE, ROBERT G., M.D.	1625 Spruce St., Phila.
1883	LEHMAN, AMBROSE E.	506 Walnut St., Phila.
1889	LE MOINE, SIR JAMES M.	Spencer Grange, Quebec, Can.
1881	LEROY-BEAULIEU, Prof. PAUL	27 Ave. du Bois de Boulogne, Paris, France.
1886	LEVASSEUR, Prof. EMILE	26 Rue Mons. le Prince, Paris, France.
1896	LEWIS, G. ALBERT	1834 DeLancey Place, Phila.
1897	LIBBEY, Prof. WILLIAM	20 Bayard Ave., Princeton, N.J.
1897	LISTER, THE RIGHT HON. LORD	12 Park Crescent, Portland Place, London, England.
1874	LOCKYER, SIR JOSEPH NORMAN, K.C.B.	Royal College of Science, S. Kensington, London, S. W., England.
1901	LODGE, SIR OLIVER JOSEPH, LL.D.	The University, Birmingham, England.
1899	LOEB, Dr. JACQUES	University of California, Berkeley, Cal.
1878	LONGSTRETH, MORRIS, M.D.	1416 Spruce St., Phila.
1904	LOVETT, Prof. EDGAR ODELL, Ph.D.	Princeton, N. J.
1892	LOW, HON. SETH	30 E. 46th St., New York.
1897	LOWELL, PERCIVAL	53 State St., Boston, Mass.

Elected.	*Name*	*Present Address.*
1869	LYMAN, BENJAMIN SMITH	708 Locust St., Phila.
1897	MABERY, Prof. CHARLES F.	57 Adelbert St., Cleveland, O.
1886	MACALISTER, Pres't JAMES	4031 Walnut St., Phila.
1897	MCCAY, Prof. LEROY W.	257 Nassau St., Princeton,N.J.
1897	MCCLURE, Prof. CHARLES F. W.	Princeton, N. J.
1896	MCCOOK, Rev. HENRY C., D.D.	Devon, Pa.
1879	MCCREATH, ANDREW S.	121 Market St., Harrisburg, Pa.
1892	MACFARLANE, Prof. JOHN M.	Univ. of Pennsylvania, Phila.
1899	MACKENZIE, Prof. ARTHUR S., Ph.D.	Dalhousie University, Halifax, Nova Scotia.
1896	MAGIE, Prof. WM. FRANCIS	Princeton, N. J.
1897	MAHAN, Capt. ALFRED T., U.S.N.	160 W. 86th St., New York.
1885	MALLET, JOHN WM., M.D.	University of Virginia, Charlottesville, Va.
1878	MANSFIELD, IRA FRANKLIN	Beaver, Beaver Co., Pa.
1878	MARCH, Prof. FRANCIS ANDREW	Lafayette College, Easton, Pa.
1901	MARCONI, GUGLIELMO	18 Finch Lane, E. C., London.
1901	MARCOVNIKOFF, Prof. VLADIMIR	Imp. Moskovsy Universitet, Moscow, Russia.
1878	MARKS, Prof. WILLIAM D.	Art Club Philadelphia.
1886	MARSHALL, JOHN, M.D.	1718 Pine St., Philadelphia.
1890	MASCART, Prof. E.	176 Rue de l'Université, Paris, France.
1867	MASON, ANDREW	30 Wall St., New York City.
1899	MASON, Prof. OTIS T.	U. S. National Museum, Washington, D. C.
1896	MASON, Prof. WM. PITT, M.D.	Rensselaer Polytechnic Institute, Troy, N. Y.
1891	MASPERO, Prof. GASTON CAMILLE	College de France, Paris, France.
1899	MATTHEWS, ALBERT	483 Beacon St., Boston.
1899	MEIGS, ARTHUR V., M.D.	1322 Walnut St., Phila.
1901	MEIGS, WILLIAM M.	1815 Pine St., Phila.
1886	VON MELTZEL, Prof. Dr. HUGO	Koloszvar, Hungary.
1897	MELVILLE, Rear Admiral GEO. W.	Navy Dept., Washington, D. C.
1899	MENDENHALL, Prof. THOMAS C.	Worcester, Mass.
1898	MENGARINI, Prof. GUGLIELMO	Rome, Italy.
1895	MERCER, HENRY C.	Doylestown, Pa.
1902	MERRIAM, Dr. C. HART	1919 16th St., Washington, D. C.
1880	MERRICK, JOHN VAUGHAN	Roxborough, Philadelphia.
1881	MERRIMAN, Prof. MANSFIELD	Lehigh Univ., Bethlehem, Pa.
1899	MEYER, Prof. ADOLPH B.	K. Zoölogisches u. Anthropologisch-Ethnographisches Museum, Dresden, Germany.

Elected.	Name.	Present Address.
1902	MICHELSON, Prof. ALBERT A., Sc.D. (Cantab.)	Univ. of Chicago, Chicago, Ill.
1899	MILLER, Prof. LESLIE W.	N. W. cor. Broad and Pine Sts., Philadelphia.
1896	MINOT, CHAS. SEDGWICK, M.D.	Harvard University, Cambridge, Mass.
1890	MITCHELL, HON. JAMES T.	1722 Walnut St., Phila.
1862	MITCHELL, S. WEIR, M.D.	1524 Walnut St., Phila.
1895	MONTEGAZA, PAOLO	Florence, Italy.
1898	MONTGOMERY, Prof. THOS. H., JR.	Univ. of Texas, Austin, Texas.
1897	MOORE, CLARENCE B.	1321 Locust St., Phila.
1905	MOORE, Prof. ELIAKIM H.	Univ. of Chicago, Chicago, Ill.
1905	MOORE, GEORGE T., Ph.D.	Hammond Court, 30th and Q Sts., N. W., Washington, D. C.
1885	MOORE, Prof. JAMES W., M.D.	Lafayette College, Easton, Pa.
1903	MORLEY, EDWARD W., LL.D.	Adelbert Coll., Cleveland, O.
1897	MORLEY, Prof. FRANK	Johns Hopkins University, Baltimore.
1899	MORRIS, HARRISON S.	Oak Lane P. O., Philadelphia.
1899	MORRIS, ISRAEL W.	225 S. 8th St., Philadelphia.
1883	MORRIS, J. CHESTON, M.D.	1514 Spruce St., Philadelphia.
1901	MORRIS, JOHN T.	826 Drexel Building, Phila.
1895	MORSE, Prof. EDWARD S.	Essex Institute, Salem, Mass.
1903	MORSE, HARMON N., Ph.D.	1117 N. Eutaw St., Baltimore.
1886	MUCH, Prof. MATHÆUS, Ph.D.	XIII[2] Penzingerstrasse, 84, Vienna, Austria.
1901	MUNRO, Prof. DANA C.	University of Wisconsin, Madison, Wis.
1891	MUNROE, Prof. CHARLES E.	Columbian University, Washington, D. C.
1886	MURDOCK, Com. J. B., U.S.N.	Navy Dept., Washington, D. C.
1881	MURRAY, JAMES A. H., LL.D.	Sunnyside, Banbury Road, Oxford, England.
1897	NANSEN, Prof. FRIDTJOF	Godthaab, Lysaker, Norway.
1878	NEWCOMB, Prof. SIMON	1620 P St., N. W., Washington, D. C.
1904	NICHOLS, Prof. EDWARD L.	Cornell Univ., Ithaca, N. Y.
1872	NICHOLS, Rev. STARR HOYT	128 Main St., Danbury, Conn.
1866	NIKITIN, Prof. SERGI	Geological Survey, St. Petersburg, Russia.
1905	NORDENSKJÖLD, Prof. OTTO	Univ. of Upsal, Upsal, Sweden.
1872	NORRIS, ISAAC, M.D.	Fair Hill, Bryn Mawr, Pa.
1895	NUTTALL, MRS. ZELIA	Casa de Alvarado, Coyoacán, D. F. Mexico.
1886	OLIVER, CHARLES A., M.D.	1507 Locust St., Phila.
1897	OLNEY, Hon. RICHARD	23 Court Street, Boston.

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1897	Ortmann, Prof. Arnold E.	Carnegie Museum, Annex, 419 Craft Ave., Pittsburg, Pa.
1887	Osborn, Prof. Henry F.	American Museum of Natural History, New York, N. Y.
1885	Osler, William, M.D.	7 Norham Gardens, Oxford, Eng.
1867	Packard, John H., M.D.	University Club, Philadelphia.
1898	Pancoast, Henry S.	78 Vernon St., Hartford, Conn.
1885	Patterson, C. Stuart	1000 Walnut St., Phila.
1900	Patterson, Hon. Edward	Supreme Court, Appellate Div., 1st Dept., New York City.
1898	Patterson, Lamar Gray	Guano, Amherst Co., Va.
1851	Patterson, Robert	329 Chestnut St., Phila.
1897	Patton, Pres't Francis L., D.D.	Princeton, N. J.
1899	Paul, J. Rodman	903 Pine St., Philadelphia.
1875	Pearse, John B.	317 Walnut Ave., Roxbury, Mass.
1897	Peckham, Prof. S. F.	150 Halsey St., Brooklyn.
1878	Peirce, C. Newlin, D.D.S.	3316 Powelton Ave., Phila.
1873	Pemberton, Henry	1947 Locust St., Phila.
1886	Peñafiel, Dr. Antonio	City of Mexico, Mexico.
1901	Penniman, Prof. Josiah H.	4326 Sansom St., Phila.
1886	Pennypacker, Hon. Samuel W.	Executive Mansion, Harrisburg, Pa.
1863	Penrose, R. A. F., M.D.	1331 Spruce St., Phila.
1905	Penrose, R. A. F., Jr., Ph.D.	460 Bullitt Bld'g, Phila.
1886	Pepper, Edward, M.D.	Care of Drexel, Harjes & Co., 31 Boulevard, Haussman, Paris, France.
1897	Pepper, George Wharton, LL.D.	701 Drexel Building, Phila.
1905	Petrie, W. M. Flinders, D.C.L., LL.D., F.R.S.	University College, Gower St., W. C., London, Eng.
1895	Pettit, Henry	Pelican Lodge, Palm Beach, Florida.
1899	Phillips, Prof. Francis C.	P. O. Box 126, Allegheny, Pa.
1896	Pickering, Prof. Edw. C.	Harvard University, Cambridge, Mass.
1897	Piersol, George A., M.D.	Chester Ave. and 49th St., Philadelphia.
1895	Pilsbry, Prof. Henry A.	Academy of Natural Sciences, Philadelphia.
1898	Platt, Charles	237 S. 18th St., Phila.
1899	Poincaré, Prof. Henri	63 Rue Claude Bernard, Paris, France.
1885	Pomialowsky, Prof. John	St. Petersburg, Russia.
1886	Postgate, Prof. John P.	Cambridge, England.

Elected.	Name.	Present Address.
1899	PREECE, SIR WM. HENRY, F.R.S....	13 Queen Anne's Gate, London, S. W., England.
1875	PRIME, FREDERICK.................	1008 Spruce St., Phila.
1899	PRITCHETT, Pres't HENRY S., LL.D.	Massachusetts Institute of Technology, Boston.
1874	PUMPELLY, Prof. RAPHAEL........	Newport, R. I.
1896	PUPIN, Prof. MICHAEL I..........	7 Highland Pl., Yonkers, N. Y.
1895	PUTNAM, Prof. FREDERICK W......	Peabody Museum, Cambridge, Mass.
1886	RADA, JUAN DE DIOS-Y DELGADO...	Calle de la Corredera baja de S. Pablo No. 12, Madrid, Spain.
1899	RAMSAY, SIR WILLIAM, K.C.B.....	University College, Gower St., W. C. London, Eng.
1901	RAVENEL, MAZŸCK P., M.D........	908 Pine St., Phila.
1898	RAWLE, FRANCIS..................	328 Chestnut St., Phila.
1899	RAWLE, WILLIAM BROOKE.........	230 S. 22d St., Phila.
1886	RAYLEIGH, The Right Hon. Lord...	Terling Pl., Witham, Essex, England.
1875	RAYMOND, Capt. ROSSITER W......	99 John St., New York, N. Y.
1898	REDWOOD, Sir BOVERTON, F.R.S....	4, Bishopsgate St. Within, E. C., London, England.
1899	REMINGTON, Prof. JOSEPH, P......	1832 Pine St., Phila.
1879	REMSEN, President IRA...........	Johns Hopkins University, Baltimore, Md.
1879	RENEVIER, Prof. E................	Univ., Lausanne, Switzerland.
1886	RÉVILLE, Prof. Dr. ALBERT........	21 Rue Guénégaud, Paris, France.
1902	RICHARDS, Prof. THEO. WILLIAM...	15 Follen St., Cambridge, Mass.
1882	ROBINS, Rev. JAMES W., D.D......	2115 Pine St., Phila.
1890	ROGERS, Prof. ROBERT W..........	Drew Theological Seminary, Madison, N. J.
1862	RÖHRIG, Prof. F. L. OTTO.........	402 S. Oakland Ave., Pasadena, Cal.
1904	ROOSEVELT, HON. THEODORE.......	The White House, Washington, D. C.
1903	ROSCOE, SIR HENRY E., F.R.S., D.C.L.	Woodcote Lodge, West Horsley, Leatherhead, England.
1891	ROSENGARTEN, JOSEPH G..........	1704 Walnut St., Phila.
1882	DE ROSNY, Prof. LÉON............	28 Rue Mazarin, Paris, France.
1877	ROTHROCK, Prof. JOSEPH T........	West Chester, Pa.
1904	RUTHERFORD, Prof. ERNEST, F.R.S..	McGill Univ. Montreal, Can.
1894	SACHSE, JULIUS F., Litt.D........	4428 Pine St., Phila.

Elected.	Name.	Present Address.
1874	SADTLER, Prof. SAMUEL P.	N. E. cor. 10th and Chestnut Sts., Philadelphia.
1888	SAJOUS, CHARLES E., M.D.	2043 Walnut St., Phila.
1897	SAMPSON, ALDEN	Haverford, Pa.
1866	SANDBERGER, Prof. FREDOLIN	University of Würzburg, Würzburg, Bavaria.
1897	SANDERS, RICHARD H.	1225 Locust St., Phila.
1882	SARGENT, Prof. CHARLES SPRAGUE	Jamaica Plain, Mass.
1902	SCHELLING, Prof. FELIX E., Ph.D.	4211 Sansom St., Phila.
1901	SCHIAPARELLI, Prof. GIOVANNI	Royal Observatory, Milan, Italy.
1878	SCHURZ, Hon. CARL	54 William St., New York.
1873	SCLATER, PHILIP LUTLEY, Ph.D., F.R.S.	3 Hanover Square, London, W., England.
1898	SCOTT, CHARLES F.	Westinghouse Electric Co., Pittsburg, Pa.
1886	SCOTT, Prof. WILLIAM B.	Princeton, N. J.
1878	SCUDDER, SAMUEL HUBBARD	Cambridge, Mass.
1897	SEE, THOMAS J. J., LL.D.	Observatory, Mare Island, Cal.
1872	SELLERS, COLEMAN, Sc.D.	3301 Baring St., Phila.
1899	SELLERS, COLEMAN, Jr.	410 N. 33d St., Phila.
1885	SERGI, Prof. GIUSEPPE	Università Romana, Rome, Italy.
1886	SHARP, BENJAMIN, M.D.	Academy of Natural Sciences, Philadelphia.
1882	SHARPLES, Prof. STEPHEN PASCHALL	26 Broad St., Boston, Mass.
1875	SHERWOOD, ANDREW	Mansfield, Tioga Co., Pa.
1899	SIGSBEE, Admiral CHARLES D., U.S.N.	Navy Dept., Washington, D. C.
1900	SINKLER, WHARTON, M.D.	1606 Walnut St., Phila.
1897	SMITH, A. DONALDSON, M.D.	1820 Chestnut St., Phila.
1887	SMITH, Prof. EDGAR F.	Univ. of Pennsylvania, Phila.
1875	SMITH, STEPHEN, M.D.	57 W. 42d St., New York, N. Y.
1897	SMOCK, Prof. JOHN C.	Trenton, N. J.
1887	SYMTH, Prof. ALBERT H.	5214 Main St., Germantown, Philadelphia.
1894	SNELLEN, HERMAN, JR., Ph.D.	Utrecht, Netherlands.
1873	SNOWDEN, A. LOUDON, LL.D.	1812 Spruce St., Phila.
1884	SNYDER, Prof. MONROE B.	2402 N. Broad St., Phila.
1873	SPOFFORD, A. R., LL.D.	Library of Congress, Washington, D. C.
1903	STENGEL, ALFRED, M.D.	1811 Spruce St., Phila.
1897	STEPHENS, Prof. H. MORSE	University of California, Berkeley, Cal.

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1884	STEVENS, Prof. WALTER LECONTE	Lexington, Va.
1877	STEVENSON, Prof. JOHN JAMES	Univ. Heights, New York City.
1895	STEVENSON, SARA Y., Sc.D	237 S. 21st St., Philadelphia.
1898	STILLWELL, LEWIS B	100 Broadway, New York City.
1902	STONEY, Prof. G. JOHNSTONE, F.R.S	30 Ledbury Road, Bayswater, London, W., England.
1904	STRATTON, Prof. SAMUEL W	Bureau of Standards, Washington, D. C.
1886	SUESS, Prof. EDUARD	K. K. Geologische Reichsanstalt, Vienna, Austria.
1895	SULZBERGER, Hon. MAYER	1303 Girard Ave., Phila.
1886	SZOMBATHY, Prof. JOSEF	Burgring 7, Vienna, Austria.
1897	TATHAM, WILLIAM	1811 Walnut St., Phila.
1886	TEMPLE, Col. RICHARD CARNAC	Port Blair, Andaman Islands, Bengal, India.
1896	TESLA, NIKOLA, LL.D	Wardenclyffe, Long Island, N. Y.
1905	THISELTON-DYER, SIR WILLIAM T.	Royal Botanic Gardens, Kew, England.
1884	THOMAS, Prof. ALLEN C	Haverford, Pa.
1884	THOMPSON, HEBER S	Sheafer Build'g, Pottsville, Pa.
1902	THOMPSON, Prof. SILVANUS P., F.R.S.	Technical College, Finsbury, Leonard St., City Road, London, E. C., England.
1876	THOMSON, Prof. ELIHU	Swampscott, Mass.
1903	THOMSON, JOSEPH JOHN, D.Sc., F.R.S.	Trinity Coll., Cambridge, Eng.
1880	THOMSON, WILLIAM, M.D	1426 Walnut St., Phila.
1885	IM THURN, EVERARD F	Govt. House, Sura, Fiji, Western Pacific.
1864	THURY, Prof. A	University of Geneva, Geneva, Switzerland.
1902	TILGHMAN, BENJAMIN CHEW	1126 S. 11th St., Phila.
1886	TOPINARD, Prof. Dr. PAUL	105 Rue de Rennes, Paris, France.
1895	TOWER, HON. CHARLEMAGNE, JR., LL.D.	U. S. Embassy, Berlin, Ger.
1903	TRELEASE, WILLIAM Sc.D	Missouri Botanical Garden, St. Louis, Mo.
1899	TREVELYAN, Rt. Hon. Sir GEORGE OTTO	8 Grosvenor Crescent, S. W. London, England.
1896	TROWBRIDGE, Prof. JOHN	Harvard University, Cambridge, Mass.
1899	TRUE, Dr. FREDERICK WILLIAM	U. S. National Museum, Washington, D. C.

Elected.	Name.	Present Address.
1882	TSCHERMAK, GUSTAV	Universität, Vienna, Austria.
1897	TSCHERNYSCHEW, Prof. THEODORE	Geological Survey, St. Petersburg, Russia.
1864	v. TUNNER, Prof. PETER R.	Leoben, Austria.
1890	TURRETTINI, Prof. THEODORE	Geneva, Switzerland.
1889	TUTTLE, DAVID K., Ph.D.	U. S. Mint, Philadelphia.
1889	TYLER, Hon. LYON G., Pres't	Williamsburg, Va.
1887	TYSON, JAMES, M.D.	1506 Spruce St., Phila.
1890	UNWIN, Prof. WILLIAM C.	7 Palace Gate Mansions, London, England.
1904	VAN'T HOFF, Prof. JAKOB H.	Univ. of Berlin, Berlin, Ger.
1899	VAUCLAIN, SAMUEL M.	1533 Green St., Phila.
1897	VAUX, GEORGE, JR.	404 Girard Building, Phila.
1905	VENABLE, Pres't FRANCIS P.	Chapel Hill, N. C.
1870	VOSE, Prof. GEORGE L.	Brunswick, Maine.
1890	VOSSION, LOUIS	Consulate of France, Cape Town, South Africa.
1903	DE VRIES, Prof. HUGO	University of Amsterdam, Amsterdam, Netherlands.
1885	WAGNER, SAMUEL	Greenbank Farm, West Chester, Pa.
1874	WAHL, WILLIAM H., Ph.D.	15 S. 7th St., Philadelphia.
1897	WALCOTT, CHARLES D., LL.D.	U. S. Geological Survey, Washington, D. C.
1904	WALDEYER, Prof. WILHELM	56 Luisenstrasse, Berlin, N. W., 6, Germany.
1873	WALLACE, ALFRED RUSSEL, LL.D.	Parkstone, Dorset, England.
1889	WARD, LESTER F., LL.D.	1464 Rhode Island Ave., Washington, D. C.
1881	WARE, LEWIS S.	54 Rue de la Bienfaisânce, Paris, France.
1897	WARFIELD, Pres't ETHELBERT D.	Easton, Pa.
1896	WELCH, WILLIAM H., M.D.	935 St. Paul St., Baltimore, Md.
1869	WHARTON, JOSEPH	P. O. Box 1332, Phila.
1869	WHITE, Hon. ANDREW D.	White Library, Cornell Univ., Ithaca, N. Y.
1878	WHITE, Prof. ISRAEL C.	119 Wiley St., Morgantown, W. Va.
1905	WHITFIELD, J. EDWARD	406 Locust St., Phila.
1898	WHITFIELD, Prof. R. P.	American Museum of Natural History, New York, N. Y.
1899	WHITMAN, Prof. CHARLES OTIS, Ph.D., LL.D.	Univ. of Chicago, Chicago, Ill.
1878	WILDER, Prof. BURT G.	60 Cascadilla Pl., Ithaca, N. Y.
1904	WILEY, HARVEY W., M.D., LL.D.	U. S. Dept. of Agriculture, Washington, D. C.

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1895	WILLCOX, JOSEPH	"The Clinton," 10th and Clinton Sts., Philadelphia.
1897	WILLIAMS, Prof. EDWARD H., JR.	53 Phillips St., Andover, Mass.
1888	WILLIAMS, TALCOTT, LL.D.	916 Pine St., Phila.
1905	WILLIS, BAILEY, E.M., C.E.	U. S. Geological Survey, Washington, D. C.
1890	WILLIS, Prof. HENRY	4036 Baring St., Phila.
1885	WILSON, JAMES CORNELIUS, M.D.	1511 Walnut St., Phila.
1887	WILSON, Prof. WILLIAM POWELL, M.D.	Commercial Museum, Phila.
1897	WILSON, Pres't WOODROW	Prospect, Princeton, N. J.
1897	WISTER, OWEN	328 Chestnut St., Phila.
1897	WITMER, Prof. LIGHTNER, Ph.D.	2426 Spruce St., Phila.
1879	WOOD, RICHARD	1620 Locust St., Phila.
1899	WOOD, STUART	1620 Locust St., Phila.
1874	WOODWARD, HENRY, LL.D., F.R.S.	British Museum, Cromwell Road, London, S. W., Eng.
1902	WOODWARD, Pres't ROBERT S., Ph.D.	Carnegie Institution, Washington, D. C.
1896	WRIGHT, Prof. ARTHUR W., Ph.D.	73 York Square, New Haven, Conn.
1900	WRIGHT, WILLIAM ALDIS, LL.D., D.C.L.	Trinity Coll., Cambridge, Eng.
1895	WUNDT, Prof. WILLIAM	Leipzig, Germany.
1899	WURTS, ALEXANDER JAY	Carnegie Technical School, Pittsburg, Pa.
1881	WURTS, CHARLES STEWART, M.D.	1701 Walnut St., Phila.
1886	WYCKOFF, Lieut. A. B., U.S.N.	Navy Dep't, Washington, D. C.
1874	YOUNG, Prof. CHARLES AUGUSTUS	16 Prospect Ave., Princeton, N. J.